AUGUST, 1943 TECHNOLOGY DEPT. ONE SHILLING

Plastics

DEALING WITH THE MANUFACTURE, USES AND POTENTIALITIES OF PLASTIC MATERIALS

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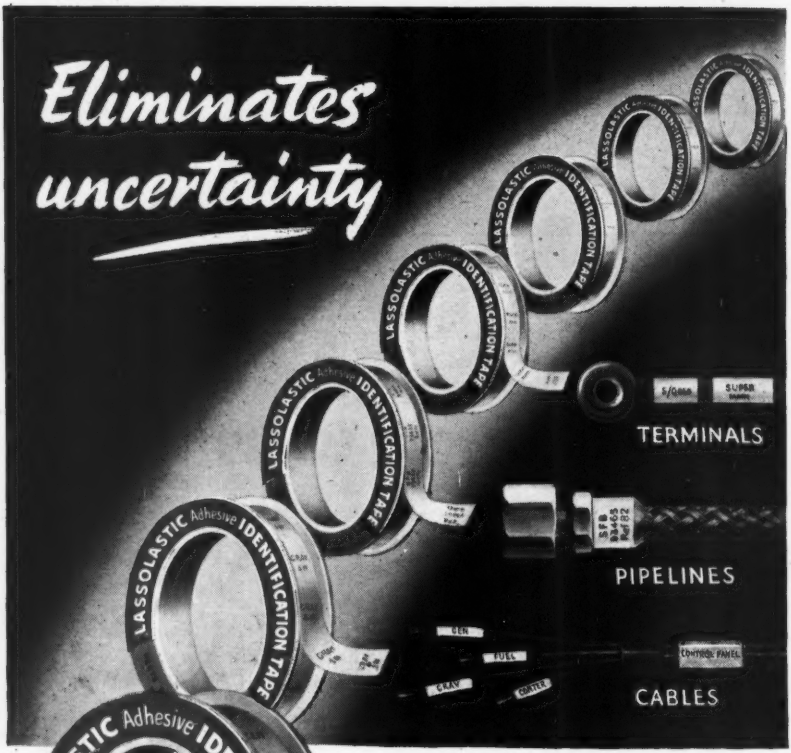

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Company's Most Prosperous Year

Development of Plastics Interests

THE 46th ordinary general meeting of Thomas De La Rue and Co., Ltd., was held in London on 29th July.

The following are extracts from the statement by the Chairman (Mr. S. S. Lamert), which has been circulated with the report:—

It is a source of sincere gratification to your Directors that they are able to lay before you the accompanying Balance Sheet, by far the most prosperous in the annals of a business whose history now extends a long way over a century. The success that has been achieved is, I venture to think, the more striking in that 20 years ago the company's finances were greatly strained. The phenomenal expansion of the business in the past five years is directly attributable to the ability and drive of your Managing Director, Mr. Bernard Westall.

In the five years to end March last our total profits amounted to £880,000, an average of £176,000 per annum. In these five years we have distributed 82 per cent. (£284,000, less tax), an average of 16 2/5ths per cent. per annum.

This year we are recommending a final Dividend of 25 per cent., making with the Interim of 10 per cent. a total of 35 per cent. for the fifteen-month period. In case any shareholder feels tempted to work out what 12/15ths of 35 per cent. is, let me say at once that our hope and expectation is that the shareholders will receive not less than 35 per cent. for the current twelve months. I should like this to be a bumper year as it is my twenty-first—and last—as your Chairman. I have intimated to my colleagues my desire to retire at the next Annual General Meeting.

During the past year we have formed separate Companies to deal with our Plastics and Stationery interests. Both of these Companies are wholly owned subsidiary undertakings of your Company. The wisdom of this step is already apparent. When the fetters on Trade are loosened, we may look forward with confidence to De La Rue Stationers, Limited, making a substantial contribution to the profits of the Parent Company.

The Balance Sheet shows a very strong position, with a Reserve Fund of £200,000 and a carry forward in the Profit and Loss Account of £62,000.

The work which we have actually in hand, and in immediate prospect, assures for us—barring major disasters—a period of great activity.

STATEMENT BY MR. B. C. WESTALL

The following statement by Mr. B. C. Westall, Vice-Chairman and Managing Director (Chairman of De La Rue Plastics, Limited), was also circulated with the report and accounts.

As the Chairman has told you, we have found it necessary during the course of the past year to form a separate Company to manage your Plastics interests. The Plastic Moulding Department had grown to such an extent that it could no longer advantageously be operated as a department of a printing business. Furthermore, greater efficiency could clearly be achieved by the appointment of a Managing Director solely engaged in the business. Accordingly we appointed as Managing Director Mr. Herbert Bridge, who has been Manager of our Plastics interests for the past three years. Mr. Bridge has done excellent work in developing your Plastics interests and with his new powers, we feel sure that he will be able to accelerate our rate of progress.

PLASTICS COMPANY'S UNIQUE POSITION

As there is a certain degree of public misconception as to the prospects of the Plastics Industry in the years after the war, it seems to me desirable to make some observations on the possibilities and limitations of your Plastics Company. De La Rue Plastics, Limited, has a number of advantages which, taken as a whole, entitle us to view the future with a steady eye. First, the Company is considerably the largest engaged in Plastic moulding. The number of our presses and the complete range of their sizes enables us to undertake work of the greatest magnitude. Secondly, being one of the oldest, if not actually the first engaged in plastic moulding, the Company has a cumulative experience particularly valuable in such a highly technical business. Thirdly, we have a very large Research and Development Department. I think it safe to say that, in the years to come, the success of De La Rue Plastics, Limited, will depend to a very large degree on the success of the Research Department, and shareholders may rest assured that the Directors of the Plastics Company regard the subject of research and development as the most important of their preoccupations. Fourthly, De La Rue Plastics, Limited, has the advantage of being interested in nearly every form of plastics, including the manufacture of the materials and the production of laminated. Fifthly, we have an admirably equipped Tool Room and a very highly skilled staff.

A SPECIALISED CRAFT

These are the advantages. I have referred, on the other hand, to limitations. It would be a mistake to imagine that plastic moulding can be economically applied to the production of practically any article. Plastics have to compete with metal and wood and in a large number of cases metal or wood are found to be more economic. In other cases plastic materials are unsuitable. Again, the steel tools from which mouldings are produced are very expensive to make and consequently moulding can only be an economic proposition when the number of articles required to be moulded is sufficient to amortise the cost of these moulds. Nevertheless, there remains a wide field in which moulding can be profitably employed.

There is one danger which, if realised, might have disastrous results for the Plastics Industry. That is the tendency that was observable before the war of big concerns putting in their own plastic mouldings department. I am convinced that manufacturers who do this are making a mistake. The manufacture of plastics is an industry which in the future will see rapid changes in methods of manufacture. It is an industry where assiduous research must accompany production. I am sure, therefore, that taking the long view, manufacturers in general will be well advised to concentrate on the production of their own specialities, leaving the making of such mouldings as they may require to those whose sole energies are concentrated on this specialised craft.

It is manifest that the prosperity of this industry depends completely on the general level of prosperity in industry as a whole. With a few unimportant exceptions, a plastic article is a component and not a complete article in itself, as, for example, the dashboard of a motor car or the casing of a radio set. Consequently the industry needs busy and prosperous customers. While, then, we are not justified in looking forward to a future as brilliant as it has been pictured in some quarters, yet there are reasonable grounds for expecting a steady expansion in the use of plastics, and of those engaged in this trade none has wider prospects than our own Company.

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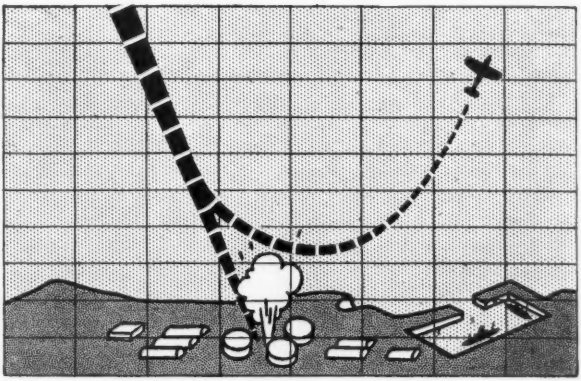

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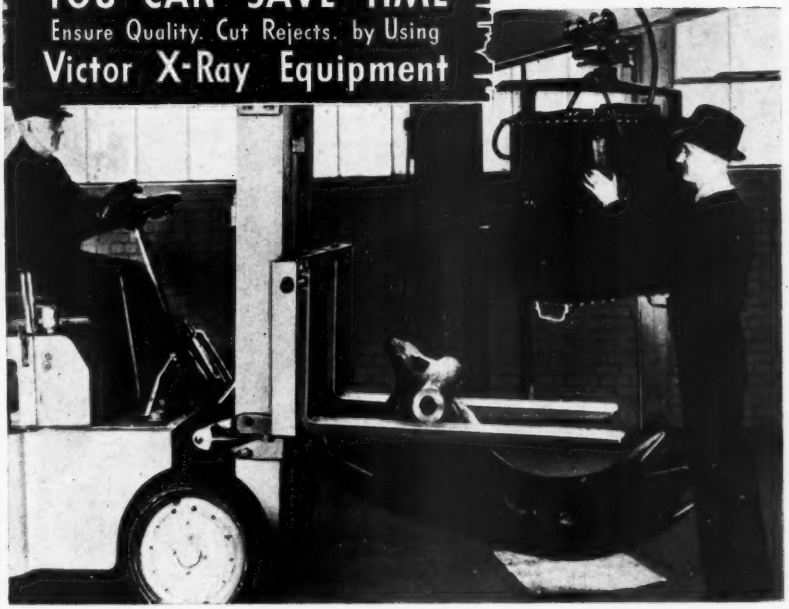

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Let the change remind you...

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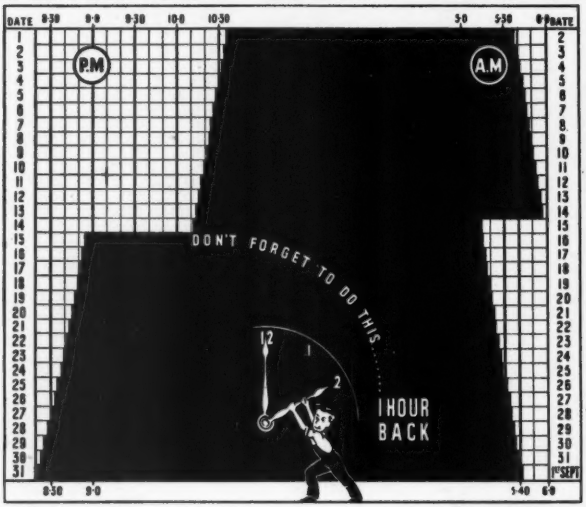

★ *Times shown are those for the London area.*

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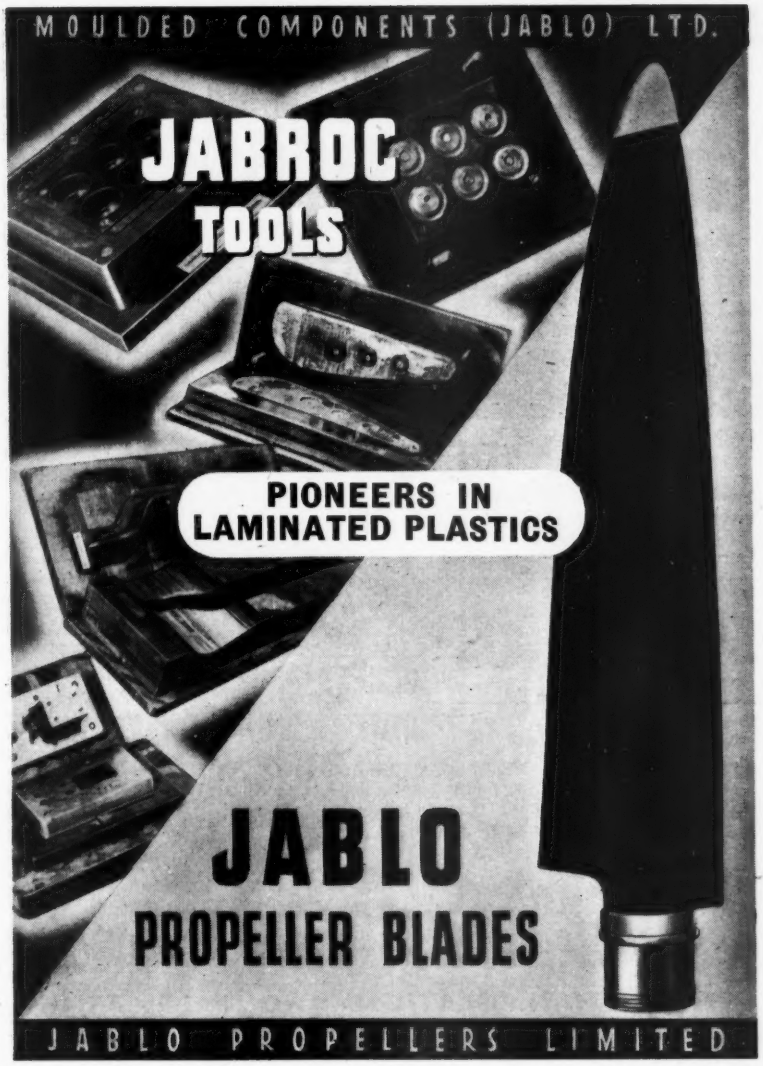
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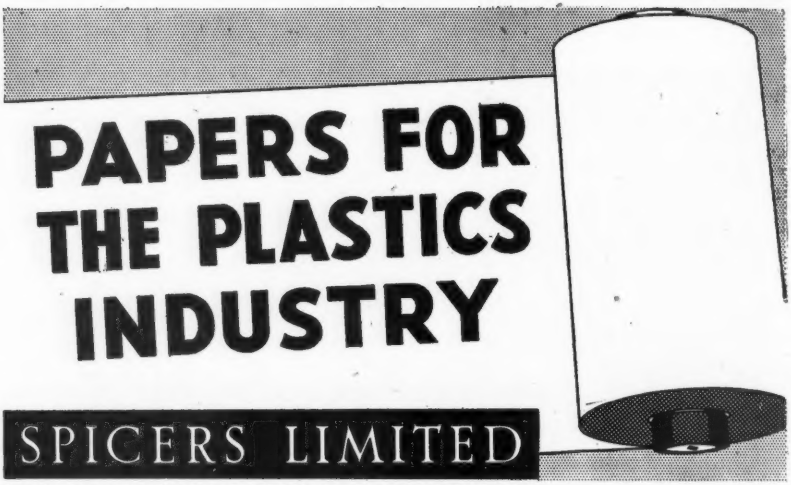

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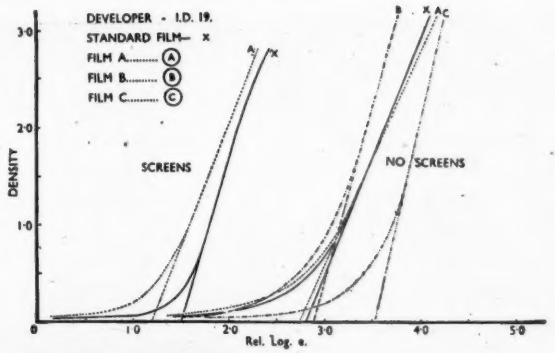

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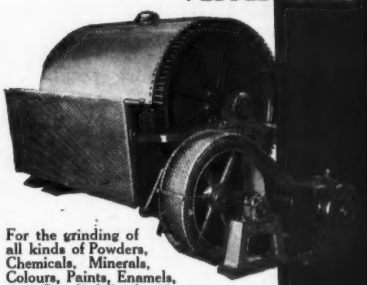

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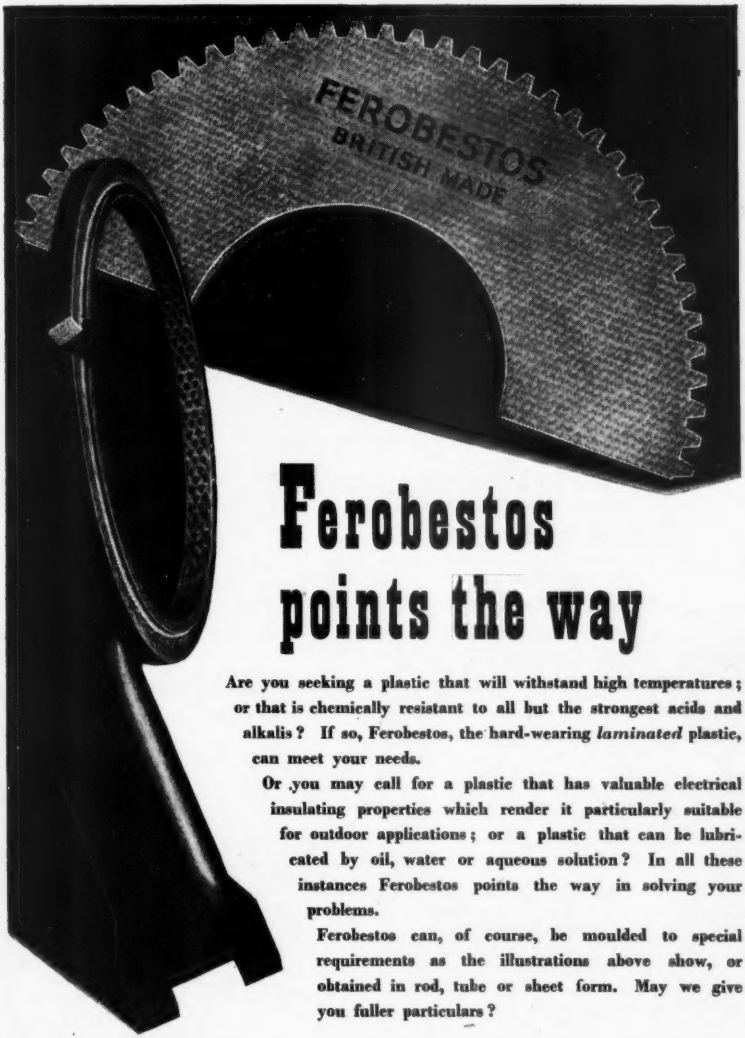

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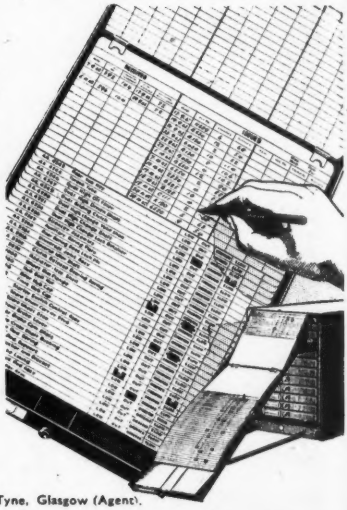

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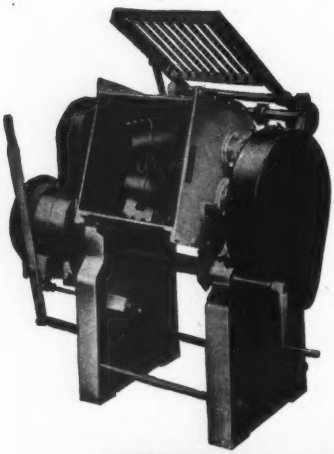

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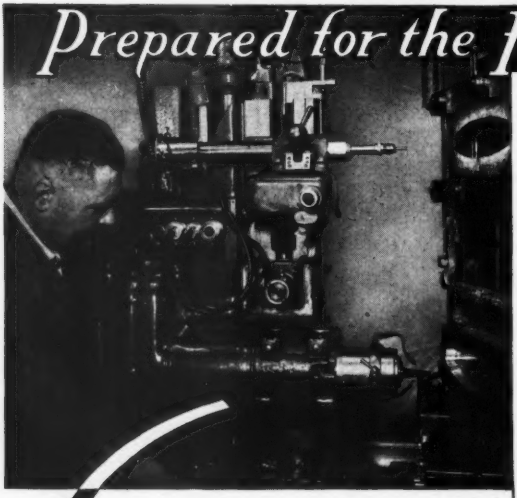

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BAKELITE PLASTICS

REGD. TRADE MARKS

Pioneers in the Plastics World

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Vol. VII. No. 75 AUGUST, 1943

Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

Proprietors - - **TEMPLE PRESS LIMITED**
Managing Director - **ROLAND E. DANGERFIELD**

Editor - **M. D. CURWEN, B.Sc., A.I.C.**
Offices - **Bowling Green Lane, London, E.C.1**

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NOTICES

All instructions, matter and passed proofs for all kinds of advertisements must reach the Head Office of "PLASTICS" by the 24th of each month to ensure insertion in the following month's issue.

TERMS—Monthly accounts, strictly net; due when rendered.

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EDITORIALS

No. 69

AT the moment of going to press with this issue we hear that " No. 69 " has been released from the Secret List. If there are still some readers who feel no ecstasy on hearing this bit of news, we beg to inform them of three facts. One, that No. 69 is a plastic hand grenade; two, that it is one of the finest jobs ever turned out by the British plastics industry and that everybody in it should be proud of the fact; and three, that while manufacture has been carried on for a long time now and a goodly number of the enemy can vouchsafe (in another world) as to its efficiency, the grenade has been kept on the Secret List.

The real aim of this note is to offer our congratulations to those moulders who have made such a magnificent job of it, to the designers of the excellent moulds, and to those who advised on the proper raw materials for an object which undergoes rough handling before being sent on its ultimate journey.

We have pleasure in reproducing on another page some photographs of the grenade and its fuse. As will be seen, there are seven moulded parts, two for the body, one protecting cap, one fuse and one fuse insert, and two small plugs. Threads abound in each part. The raw materials are partly wood-filled phenolic and partly special impact cotton-phenolic. As readers will no doubt realize, there is ample scope for a plastic bomb which, while killing the enemy, yet will not hurt the thrower. In our next issue we hope to describe the mouldings and manufacture in greater detail.

Some who read our previous notes in the May issue appear to have misconstrued our attitude towards the Secret Lists of the various forces. We have, of course, nothing against Secret Lists as such, which are maintained, very properly, to prevent the enemy getting early information regarding new weapons. Our sole grouse against Authority is the time-lag maintained before release is made. Judging from the paucity of information allowed British journals and the plethora found in foreign journals, one would imagine that the British plastics industry has done little or nothing to aid the war effort, with the possible exception of making transparent windscreens for aircraft. How far this is from the truth, only the British plastics industry and the Navy, Army and Air Force know.

There is an urgent need to tell the outside world, in effect our future customers in peace-time, of some of the very fine jobs that are being done.

The First Plastic

THE tiny Anglo-American war, which was started last month on the declaration by our old friend, Lougee, of California, that the American, Hyatt, made the first synthetic plastic in 1869, will, we hope, be ended almost as soon as it started.

In our July issue we stated that one Daniel Spill made Xylonite (cellulose nitrate) on a commercial basis before Hyatt. This is not all the story, for Mr. S. B. Turner, of B.X. Plastics, Ltd., sends us a pamphlet issued by his company entitled " Who was the Pioneer of Plastics," embellished by a photograph of Alexander Parkes.

The text of this pamphlet is as follows:—

" The first commercial plastic was a thermoplastic, invented during the last century; the thermosetting family came about 50 years later. Alexander Parkes, born in Birmingham in 1813, started his experiments in the 1840s and took out his initial patent for a new substance

known as 'Parkesine' in 1855. Worked-up samples were shown at the Great Exhibition in London, 1862, and at the Paris Exhibition, 1867. Shortly afterwards 'Parkesine' was renamed 'Xylonite' in England and 'Celluloid' in America.

"The company formed to develop 'Parkesine' came to a premature end, but Daniel Spill, one of Parkes's assistants, acquired the patents and carried on a small business in the East End of London. Spill's company, The British Xylonite Co., Ltd., amalgamated in 1879 with a business started by the grandfather of our present chairman, and BX Plastics is a subsidiary of The British Xylonite Co., Ltd. Thus it has a history going back nearly a hundred years to the time of Parkes's early experiments."

It is interesting to note that the evidence given before the Departmental Committee on Celluloid in January, 1913, contains a statement by Vivian Byam Lewis, Professor of Chemistry at the Royal Naval College, Greenwich. In this he says, ". . . Later it was found that collodion cotton could be gelatinized by kneading it with a solution of camphor in alcohol and then could be cast or moulded into any desired shape, the alcohol being evaporated, and this was first done by Daniel Spill at works in Hackney, and an excellent imitation of ivory was made which was sold as 'xylonite.' The manufacture was taken up and improved in the United States by John Hyatt, to whom the invention is often ascribed . . . ."

Timber Resources

AT the end of the last war it had been solemnly agreed that re-afforestation of our depleted woods and forests should be carried out, and was a most urgent need in our post 1914-1918 war economy. In view of the fact that to-day we have no more mature wood in the country than we had in 1918 it makes one ponder on the lack of energy displayed by past Governments or the Forestry Commission. No doubt, just as our Navy and Army had been axed, so had all the fine promises to lay the foundations of our future wood supplies been swept into the limbo of lost hopes.

Again the same problems arise, only to-day, in view of the vast building programmes that must commence as soon as hostilities cease, they are more urgent. Again they are being debated in Parliament and the Forestry Commission proposes to replant 600,000 acres and afforest another 500,000 acres. Sir William Jowett recently discussed the problem in the House and said that if Britain should find herself at war in 50 years' time, she would be practically without timber, and that it is a matter of great importance that we should now, as soon as possible within the next decade, plant to a very considerable extent.

We wonder if the Forestry Commission has the foresight it should possess. One million one hundred thousand acres appears at first sight to be a great area. But, reduced to other figures, it is no more than 1,720 sq. miles, equivalent to a square whose length is only about 41½ miles; in short, an area less than one-third the size of Yorkshire.

Can such an area suffice even a small fraction of the demands of an industrialized country and can we afford to revert to the pre-war situation of importing nearly all our timber from abroad? What is worse is that the large exporting countries themselves are feeling the pinch and that the resources of Russia and Canada are becoming less accessible with the years. Germany has probably devastated the forests of Central Europe. Re-afforestation has, in fact, become a world problem.

We must make no mistake about it for it vitally affects the plastics industry. We should all make it our business that at least in this country a virile programme should be set afoot.

Wood pulp is now part of the plastics industry, whether it is used as paper or made in fibres, although we cannot hope to set up forests for making wood pulp. Wood flour manufacture is part of the plastics industry and so is the production of veneers and plywood. The curve of

production of resin-treated and resin-bonded cellulose and woods rises rapidly and will continue to rise even faster after the war. There is not only a need for energetic afforestation and re-afforestation, but also, concurrently, the need for research on the best type of timbers for specific plastic jobs.

Gas Research

THE gas industry is determined to carry out long-term research work on a variety of problems which affect its own organization and subsidiary industries. In taking this wise step it will no doubt work in collaboration with, although in detail quite separate from, the coal research advocated by the British Coal Utilization Research Association, which body announced some four months ago that £200,000 per annum for five years would be spent on this broad subject. It will also be remembered that about the same time the Parliamentary and Scientific Committee recommended the expansion of coal utilization research on such a scale that ultimately several thousand research workers would be employed, and that disbursements would involve the expenditure of funds running into several million pounds per annum

The action of the gas industry, which, as we have already pointed out, has done much more research on coal gas and by-products of coal in a year than the coal owners did in a hundred, is one by a virile section built up on scientific endeavour. It has now compiled a 40-page report of the plans of the gas industry and is to be presented to the Ministry of Fuel next month.

It is the result of two years' deliberation by a committee of 14, representing gas undertakings and appliance manufacturers. It recommends:—creating a fuel advisory council to guide and advise the Ministry on technical matters; setting up a national organization representing the industry, to co-ordinate its development; revising legislation to meet post-war needs; instituting a tribunal to deal with the industry's domestic problems; working out a flexible national plan for a post-war fuel policy; and expanding the suggestion in the Scott Report that local grid systems should be extended.

The complete co-ordination of the gas and appliance industry and the creation of a grid system is an essential step in the progress of any industrial nation and would appear especially applicable to a country as compact and as gas-minded as this is. Such a movement would not only affect economically our future homes, but also every factory that can employ this means of heating.

The Welding of Plastics

DURING the last six months a considerable amount of information of a general nature has been released regarding the technique of welding plastics by heat. It relates, of course, to the thermoplastic materials and deals with two distinct processes—heat welding methods akin to metal welding, utilizing a hot-air pistol and welding rods made of plastics, and, secondly, welding methods utilizing high-frequency currents. Both possess some promise, but in quite distinct fields. The first has reached fairly wide application in Germany, where the Four Years' Plan limited the use of metals, more specifically for the fabrication and installation of piping for household and chemical engineering usage. Welding of thick sheet for other structural jobs has also been carried out.

The welding by high-frequency current promises to make a special field for itself in the welding of thin plastic sheet for balloon fabric and clothing (see p. 349), although thick sheet can also be welded. The apparatus needed, quite apart from the machines producing the high-frequency current, naturally limits the employment of this method so that the welding of pipes by it seems out of the question. It is also extremely problematic whether it will be worth while welding those plastics such as polythene and polystyrene with a low power factor because of the size of current-producing machines required.

No. 69

The Anti-personnel Hand Grenade, made of shock-resisting phenolic resin. A high watermark in British design and British workmanship

The photos show the complete grenade and the breakdown of its component parts.

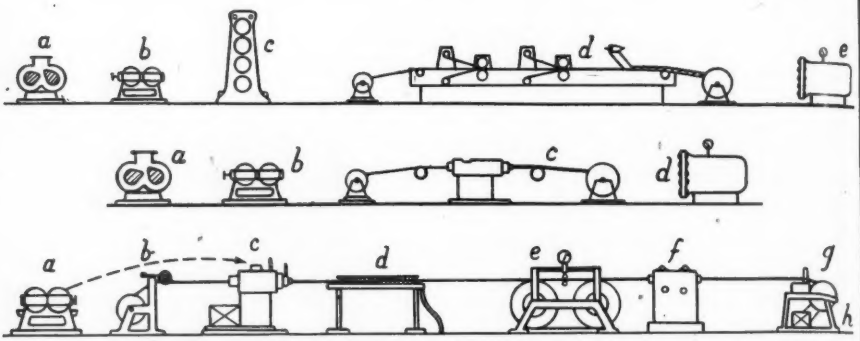


Fig. 1 (uppermost illustration).—Longitudinal application of rubber insulation: a, masticator; b, mixer; c, calender; d, application of rubber strip to conductor; e, vulcanizing plant. Fig. 2 (centre).—Insulating by extruded rubber: a, masticator; b, mixer; c, extrusion plant; d, vulcanizer. Fig. 3 (lower illustration).—Insulating with P.V.C. by extrusion: a, mixer; b, wire coil; c, extrusion press; d, cooling; e, f, g, finishing, testing and coiling of insulated wire.

Insulating Cables with P.V.C.

An Account, Based on Continental Publications, Comparing the Techniques of Insulating Conductors with Rubber and Polyvinyl Chloride

FOR the electrical protection of conductors it is, in general, necessary to apply uniform and tightly closed layers of an insulating material around them. The efficiency and quality of the insulation attained then depends on the electrical properties of the insulating material, the thickness of the layer, and the method of its application to the conductor.

Before the advent of the newer thermoplastic materials (particularly the continental "Igelite") rubber was mainly used, the uncured mix being applied either in layers lengthwise or extruded over the core.

In the first method, bands of the insulating material are rolled on to the wire by means of profiled rollers, the two halves being pressed together, thus forming two seams in a longitudinal direction. After curing the joints were considered sealed and water-tight. The mix used consisted of natural rubber, fillers, sulphur, accelerators and pigments, masticated and rolled to a homogeneous texture (Fig. 1). The sheet obtained in this way is calendered and cut into bands of the desired width, and pressed on to the wire as described. In some two covers are stipulated.

Before the steam curing operation, a band is usually wrapped round the wire. After curing, the cable is plaited with thread and impregnated.

Plant for this work is not entirely continuous, but those sections in constant operation attain speeds up to 96 ft. per min., and in modern equipment, consisting of batteries of units, as many as 24 wires are covered simultaneously.

The extrusion method is preferred in the United States. The uncured mix goes from the masticator to the rolls, where it is slightly heated and taken off in strips (Fig. 2), which pass into the tube press. Here it is fed by a worm into the extrusion nozzle and formed as a tube

round the wire which runs through the extrusion head. (Fig. 3.)

The feeding direction of the mix is usually perpendicular to that of the wire, which is drawn through the machine by means of a device operating with stepless speed variation to give constant speed. When the worm is supplied with a uniform amount of the mix, the wire is coated with a uniform insulating layer. Parallel wires can be covered with a single layer of insulator on this type of machine.

After covering, the insulated wire is powdered, wound on spools, and the rubber vulcanized. A continuous vulcanizing process has been developed. In this the cable passes through a heated tube, where the curing is started, special accelerators in the mix assisting in completing the process.

Comparative Working Methods for P.V.C. and Rubber Cables

Extrusion presses are, in principle, suitable for the working of all materials having plastic properties, including the thermoplastic resins, but, whereas rubber is treated at relatively low temperatures in order to prevent premature curing, thermoplastic materials must be extruded at higher temperature. The working temperatures of mixtures containing polyvinyl chloride (Igelit PCU) vary, according to the composition, between 160 and 180 degrees C. Polyvinyl chloride is, in particular, suitable for cable-covering purposes; addition of plasticizers, the necessary flexibility for this purpose, may be obtained. Properties are further varied and adapted according to special requirements, and working may be carried out, even at lower temperatures, than those specified, but tensile strength and the strength at low temperatures then deteriorate. On the other hand, overheating of the material causes scorching or disintegration.

Extrusion presses for such high temperature had to be specially developed. No ultimate solution has yet been found. In newer plant preferably electric heating is applied, sometimes only as an auxiliary means in combination with steam heating. Sometimes oil burners are used. A special characteristic of these heating systems is their subdivision into zones in order to obtain an increasing temperature gradient from entrance to exit.

For the working of polyvinyl chlorides the following principles are applied:— Feeding of (a) cold mass, (b) preheated and plasticized mass, and ultimately (c) of heated mass ready for extrusion.

With reference to (a), the cold or slightly heated mass is fed into the extrusion machine in chip or band-form. When moved from the feeding funnel and nozzle, the mass is uniformly heated (at least up to 160 degrees C.), homogenized and thoroughly kneaded. Owing to its low heat conductivity, the not very ideal heat transfer conditions in the machine, a high heat potential is necessary; i.e., the surface temperature of the heated area should be as high as possible, in order to increase throughput capacity; hence there is a risk of damage to the plastic mass, and this may lead to imperfections in the finished insulation.

If the temperature be kept lower, the risk is that cold parts of the mass are carried along in the shape of knots, and this may also lead to defects in the finished product. The advantage of this method is, however, that no special machines for pre-treatment, such as kneading machines and rolling mills for mixing are required, as the mass may be obtained ready for use from the manufacturer in chip, bar or band form. As their capacity is relatively small, machines of this kind, which are cheap, will be suitable in the main for small manufacturers. From a plant of this kind, consisting of a dry-oven, an extrusion press of 2¾-in. diameter, with feeding and winding devices, an extrusion capacity of about 62 ft. per min. can be obtained for a cable of 2.5 sq. mm. wire cross-section.

The capacity of the extrusion press can be increased by feeding to it a well-heated plasticized mass. This can be achieved in a simple way by preheating and plasticizing as a preliminary operation in a

simple extrusion press; experience has shown that the kneading action of the worm provides quick heating and mixing. The mass supplied by the first machine is then fed to the second plant.

The capacity of the first press has to be dimensioned in such a way that it supplies the amount necessary for the second, and the final extrusion speed attained will depend directly upon the capacity of the first unit. With a preliminary machine of 4 ins. worm diameter sufficient mass may be prepared to supply a machine of 2⅜ ins. worm diameter for an extrusion speed of about 230 ft. per min., the first plant being fed with strip or chip plastic. The preliminary extrusion press can be of simple and robust design, as no accuracy is required.

Worm Designs Compared

As the worms in each respective machine have to fulfil different functions they cannot be interchanged and used arbitrarily as first and second machine if any attempt at attainment of very high output be made.

The special characteristics of these worms are: threads per inch, pitch, change in pitch—width and depth (progression), ratio of diameter to length, r.p.m. of worm. Considerable differences in these factors exist between each type of machine and depend on the use made of it.

The most economic method is to preheat the mass on a mill up to the real working temperature of 160 degrees C. The polyvinyl chloride powder, mixed with plasticizers and pigments, may be heated and fed in slug form to the extrusion press. This method requires, in general, two mills, as the production of a homogeneous well-plasticized mass takes some time. In order to obtain uniform flow, the rolls may be fed alternately, or one mill may be used only for the pre-kneading, the second being used to work up the finished mass.

With a worm diameter of 2⅜ ins. and a wire of 2.5 sq. mm. cross section, it is possible to reach an extrusion speed of 400 ft. per min., corresponding to a plastic consumption of about 2.2 lb. per min.

The use of a two-high mill of about 12 ins. roller dia. and 26 roll length is assumed. With a rolling time of 8 mins. (this is necessary completely to plasticize the mass) the quantity given corresponds to a feeding unit of 22 lb., a capacity which can be just achieved on machines of this size. The extrusion machine can work this amount when the worm is designed accordingly and operates at a sufficiently high speed. Fig. 4 shows the arrangement of a complete plant of this kind.

It is evident that the design of the extrusion head is of decisive influence on the capacity of these machines. The movement of the mass is hindered by the length of the path it must travel, by friction along the walls, by deviation of true flow and by projections which directly hinder flow.

The length of the head cannot usually be reduced by reason of design, otherwise no space would be available for the introduction of the wire-carrying parts. Friction losses at the die walls can be reduced by polishing and hard-chromium plating. The deviation of flow of the mass in the case of the head with axes crossing at 90 degrees has been reduced, with recent heads, by bringing the axes to bear at 60 degrees and even at 35 degrees, thus achieving a distinct improvement leading to increase in extrusion output.

Promoting Uniform Flow

Considerable resistance arises in the channel which guides the wire past the die head. This portion of the apparatus is usually provided with independent electric heating, and its size cannot be reduced below a given value, indeed, it occupies a considerable portion of the free space in the head.

The mass, fed by the worm, is under high pressure and will take obviously the shortest path towards the nozzle; this causes a non-uniform speed distribution over the whole cross-section, hence bulk-flow speed at some points, i.e., blind

corners, is very slow or even nil, a state of affairs leading eventually to burning. This trouble can be avoided by a so-called "runover," which is provided on that portion of the head where, according to previous experience, the greatest damming effect will occur. On older plants without stepless speed variation the "overrun" was utilized for the adjustment of the thickness of insulation.

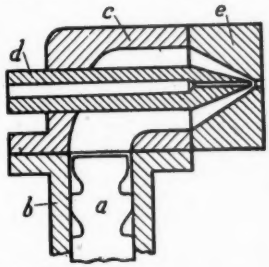


Fig. 4 (right).—Cross-section of rectangular-feed-type extrusion head: a, feed worm; b, heated cylinder; c, die head; d, lead-in for wire; e, mouth of die.

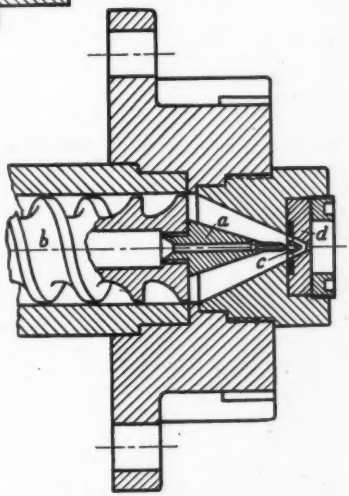
Non-uniform speed distribution causes the mass to enter the die orifice non-axially, thus a lateral pressure arises on the wire, making the thickness of the insulation layer on one side greater than on the other. Extruding machines with worms are usually equipped with centring devices which allow the nozzle to be centred with reference to the conductor; these can, however, be adjusted only when the wire is running, thus making difficulties in checking the concentricity.

Burning of the mass, and difficult centring, considerably hinder production. Both problems can be avoided by the very simple arrangement of the worm axis being central to the axis of the wire. For this purpose the wire has to be conducted through the axis of the worm. In most cases the latter is provided with a central hole for the reception of a heating or cooling device, but the heating arrangement can be dispensed with when working pre-heated polyvinyl chlorides and other thermoplastic materials.

With earlier designs of this kind, attempts were made to feed the wire through a stationary channel and thus to centre it at the output side of the worm. Such designs failed owing to the fact that the seal between the rotating worm and the stationary channel could not be maintained under high pressure. Long labyrinth seals, stopping bushes, graphite and carbon seals, as well as bearings with hardened surfaces, all failed after a relatively short period of use.

The solution to the problem was found in the design shown in Fig. 5. Here the channel was formed as an extension of worm b, and therefore rotated with the

Fig. 5 (below).—Cross-section of the improved axial-feed-type extrusion head: a, lead-in for wire; b, feed worm; c, mouth of die.



worm. The floating bearing of the front portion of the worm implies that the channel is not absolutely axial and hence cannot be used for the actual centring of the wire. For this purpose the wire is guided, shortly before entering the nozzle, through a small but stationary centring die, e. The point of the channel has a hole about 0.1 mm. larger than the wire diameter.

After leaving the point of the channel, the conductor passes a short distance through the extrusion head, after which it is guided through the centring die, c,

being subsequently covered with insulating mass, which is formed into the actual insulating layer at the die mouth. As the wire passes freely through the mass for some distance, the force required to pull it through is greater than in the old design; the stresses arising, however, can be taken by the conductor without stretching or breaking taking place.

In order to obtain high output capacities with this new extrusion head, the worm had to be provided with very deep threads; simultaneously, its speed was increased to 90 r.p.m. Under these conditions the mass passes through the whole extrusion machine in the short period of about 30 secs., hence it is not so important that the plant be intensively heated. If the mass leaves the rolls at 170 degrees C., the finished insulation has little chance of cooling down during the short interval of 30 secs. in the machine. The essential requirement for working of polyvinyl chloride is that operating temperatures do not drop below 160 degrees C., and this condition is observed in all cases. In order to obtain a bright surface it is advisable to heat the die mouthpiece to about 185 degrees C.

Owing to the low heat level obtaining during operation (during trials, steam at 47 lb. per sq. in. was used), any mass which may remain in the machine is very unlikely to be burnt, even if the plant temporarily stops, as for example, in introducing a new reel of wire or changing shift. When starting up the plant again after stoppage, it is important that any insulating material remaining in the locality of the channel and die head should be ejected before the wire be introduced; this should be done only when fresh hot insulator begins to come from the die orifice. Actually the empty volume of the head and worm is so small that the amount ejected in this way would be about 1 lb., and this can be returned for re-use as it will not have been over-heated.

It should be noted that the use of feed rolls in the charging funnel of the press avoids the necessity of the operator forcing the plastic down into the feed worm. Actually the preliminary feed rollers rotate in a direction opposite to that of the worm into which they feed the plastic automatically.

The new type extrusion head described can be used both with natural and synthetic rubbers. With Buna considerable advantages are claimed, not only in increased working speed, but also in easier compounding of mixes.

The worm in the new head has threads of uniform pitch and acts, therefore, purely as a conveyor device. Worms with progressive pitch exert a masticating action but suffer reduction in feeding capacity. Nevertheless, this latter type of worm, correctly dimensioned, can be used with advantage on machines which are fed with cool or but slightly heated polyvinyl chloride. Too pronounced a progression on the pitch of the worm is to be avoided.

Lighting of the Future

Lord Brabazon, president of the Electrical Development Association, recently gave some views of the future trend of lighting and other electrical equipment for the home. These will all affect the plastics industry directly. He points to the coming of more rigid standards and promises fluorescent lamps that will give the home two and a half times the present illumination at no greater consumption of current than now; invisible heating of rooms from the walls themselves; "rationalized" wiring installations, with all meters, main switches and fuses in a compact wall cabinet containing instantly interchangeable fuses that a child can handle in safety; one standard size of plug and socket for all purposes; radio direct from the mains; refrigerators at a price within the reach of the average pocket.

One form of invisible heating consists of wires woven into plastic boarding which can be produced as a panelling in any desired colour system.

A Long Pull— and a Strong Pull

A WACO Glider carrying important pharmaceutical chemicals to Russia has been towed across the Atlantic by a Douglas Dakota of the R.A.F. Transport Command. The tow-rope was of nylon, and the steel attachments for towing were designed to stand a pull of nearly 10 tons.

Once again plastics makes history and nylon has entered into an industry far older than history itself. Since the dawn of time ropes in one form or another have been made from hides, fibres and so on. With the exception of the introduction of machinery, the manufacture has altered not a whit; nor have their uses, which range from hanging, tug-of-war, tight-rope walking, punishing sailors with ends, skipping, prevention of ships leaving jetties, cowboy rodeos and so on. Ropes are also sometimes used for hauling things and driving machinery.

While the manufacture of rope is a most fascinating one, yet, like nearly all ancient industries or arts, there has been, on the whole, little improvement in the final product except from the point of view of care in selection of raw material. While the rope is amazingly strong and has useful attributes for the transmission of power, yet the life of the rope depends very much on the care taken of it. Apart from mechanical injury, breakdown through chemical attack and damage following moisture absorption and consequent fungal or bacterial action can seriously shorten the useful life. This fault is inherent in all natural cellulosic materials, and the ordinary lubrication of strands during manufacture expressly to resist the entry of moisture has little beneficial action after a time lag. It is also noteworthy that in the manufacture of cord and twine the yarns are saturated with starch, which would not appear to be a very suitable material to resist water, insect or bacterial attack. The rope industry has never been very interested to consider the treatment of yarns with special resins to provide such resistance to the finished rope or cord. Indeed, the general treatment has been restricted mainly to the simple application of tar. In more recent years the use of metallic soaps, e.g., copper salts of organic acids, has proved of some success.

Apart from its inherent strength, nylon is extremely water resistant, and its long life as a rope material can be inferred. Its water resistance doubtless runs parallel with its resistance to bacterial or fungal attack. Hence its success in use as fishing lines.

Squadron-leader Seys, D.F.C. (left), captain of the glider, and Squadron-leader Gobeil, co-pilot, examining the nylon tow-rope before embarking on the first towed glider flight from Canada to Great Britain.

World's Industry Employs Plastics

ELECTRICAL

Protection of overhead-cable equipment against normal atmospheric corrosion and moisture and industrial gases is considered by Perlick in "E.T.Z.," vol. 60, p. 1009. The author refers particularly to difficulties entailed with bimetallic connections, one element of which is in aluminium; a system of plastic embedding is described which is said to give perfect protection even for copper-aluminium junctions. The use of nitrocellulose lacquers for coating steelwork is compared with that of the older painting techniques. "Chromotekt," an inhibiting coating based on a synthetic resin (plus an insoluble chromate?), is referred to.

GENERAL ENGINEERING

Thermal insulation with Iporka is described by Seiffert in "Wärme und Kaltetechn," 1941/43/153. The nature of this material is not stated, but it is claimed that tests have shown it to be but little inferior to cork for temperature gradients of up to 20 degrees C., for heat levels down to −15 degrees C. As opposed to cork, Iporka is less amenable to attack by fungi, less absorbent to dirt and moisture, and cheaper than cork. **Testing of P.V.C.** is dealt with by Berger in a communication from the raw-materials laboratory of the I.G. Farbinindustrie (Ludwigshafen Works). Volatile constituents should not exceed 0.4 per cent. by weight, after heating for three hours at 110 degrees C. Ash content will vary, but for cable insulation should not exceed 1.5 per cent.; a special method is described based on destructive distillation with concentrated sulphuric acid. Chlorine determination (of value in ascertaining the precise type of P.V.C. being examined) is carried out by a modified Baubigny-Chavanne method; the chlorine content may be from 46.5 to 55.5 per cent. Chemical stability is checked by pH determination of water in which the plastic has been boiled for given periods; silver-nitrate nephelometric tests should give less than 0.1 per cent. free chlorine. Mechanical tests are also covered. The effect of overheating, it is noted, may be to lower both mechanical and chemical stability. **Influence of pressing conditions and resin content** on the properties of laminates were investigated by Küch and reported (in abstract) in "Kunststoffe," vol. 30, p. 42. The important relationship between resin content and pressing load is emphasized. **Elastic modulus by dynamic method** is described by Fröhlich in a communication from the Institute for Technical Physics and Electrothermy, Tech. Hochschule, Hannover. The misleading results obtained by static systems are commented upon. In the method described, a mechanical-pneumatic device is used to excite the test piece, resonance being recorded by a suitable electro-magnetic device. At 20 degrees C., astralon has a modulus of 375 kg./mm.²; cellulose acetate 210 kg./mm.²; celluloid 280 kg./mm.²; hard rubber 300 kg./mm.²; mipolam 375 kg./mm.²; laminated paper 1,450 kg./mm.²; plexiglas 500 kg./mm.²; polapas 1,000 kg./mm.²; trolit 600 kg./mm.²; polystyrene 375 kg./mm.²; cast phenolic resin 400 kg./mm.²; vulcanized fibre 650 kg./mm.². **Dies for deep**

injection mouldings are dealt with by Gastrow in " Kunststoffe," 1942/32/311. The account is strictly practical, illustrated with working drawings of actual dies, and forms a concluding section to the author's article on dies for shallow injection mouldings appearing in " Kunststoffe," 1942/32/274. **Protection of wooden pendulums** against water absorption formed subject of research by Vieweg and Gottwald reported in " Feinmechanik und Präzision," 1942/50/157. Wooden pendulums commend themselves on account of their low thermal expansivity, but length variation with change in humidity is a disadvantage. A royal pendulum was coated with Oppanol by application of an emulsion. It was found that variations were reduced to one-fifth of those observed before the pendulum was coated.

MOTORS

Plastic bodywork for experimental cars is described by Troesch in " Schweiz-Bauztg," 1942/119/81. The account deals mainly with investigations carried out by Ford in 1941. The success achieved with stressed-skin construction on a tubular metallic framework is commented upon. Phenolic resin with wood-fibre, flax and hemp fillers was tested, some soya resin being incorporated in the mix.

CHEMICAL

Resistance of Polyvinylacetal resins to strong alkali solutions (cold) is dealt with, *inter alia*, by Gibello in " Rev. gén. Caoutchouc," 1942/18/198. The author describes very comprehensively the chemistry of these resins, their method of manufacture, their physical properties (particularly with reference to solubility in organic solvents), and pays special attention to the need for their careful purification in order to assure stability of the finished product in use. Other fields of application, such as packaging and aircraft, are also touched upon.

FANCY GOODS

Surface processing of mouldings is examined in practice by Turnwald in " Kunst. Techn.," 1941/11/245. The author points out that the normal flat, smooth surface obtained may not always be commercially acceptable. Fine-punching, knurling or milling to obtain finishes not very different from sandblasting are of limited value and may cost as much as 6d. per sq. cm. to carry out. More varied and cheaper effects may be obtained by " printing off " designs on to the flat surface in synthetic-resin-base lacquers, particularly for the mass-produced fancy-goods line.

MISCELLANEOUS

Dimensions of moulds for thermosetting resins are frequently based on rule-of-thumb methods, according to Weprek in " Kunststoffe," 1942/32/217. It is pointed out that this may lead not only to imperfect mouldings, exhibiting porosity, or regions of unequal density, but also to waste of energy in the press and to undue wear of the mould face. To overcome this difficulty, attention is drawn to the need for careful distinction between applied forces and resultant mould pressures, and to means for estimating accurately, energy requirements for closing the die and applying pressure, and for opening the mould.

Surface finish of the die parts is important in promoting or diminishing power losses and in prolonging mould life. Typical analyses of mould dimensions and forms for various press types are finally presented. **Complex synthetic resins** formed by reaction between formaldehyde and polyamide compounds are discussed in detail by Scheele and Steinke in "Kolloid Z.," 1941/97/176. The azomethine resins obtained exhibit long chain molecules and are, in general, soft and soluble with difficulty in even the most effective of organic solvents. Possible reasons for this are advanced, and reactions between the resins and cellulose ethers and esters are examined. The aniline resins are the best-known representatives of the group. **Constitution of highly polymerized condensates especially of AXF** is examined by Kei-iti-Sisido and Syunziro Katê in "J. Soc. Chem. Ind." (Japan), 1940/43/232. This product, produced by the controlled reaction between acetylene dichloride and benzene in the presence of aluminium chloride, is of a rubber-like nature, and has been introduced in a commercial form to the American market. **Quinone-inhibition of styrene polymerization** is examined by Kern and Feuerstein in "J. Prakt. Chem.," 1941/158/186. The authors point out that the inhibitive powers of the quinone are limited with respect to time, and that after an induction period depending on the quinone concentration, polymerization proceeds at the speed attained in the absence of the inhibitor. It is shown that the action is due to the formation of an unstable addition product of quinone and styrene. Similar compounds are formed by substituted quinones such as 1:4 naphthoquinone, but not by the anthroquinones. **New methods for working polyvinyl chloride** are described in detail by Wick and Iloff in "Kunststoffe," 1942/32/137. In particular, a system of hot stamping is considered. This enables mass production of articles to be undertaken in both the soft and hard forms of P.V.C. at economical rates. **Colour measurement of plastics** is discussed by Schäfer in a dissertation read before the Technical Physics Institute of Darmstadt and abstracted in "Kunststoffe," vol. 30, p. 4. Special attention is paid to the relationship between the colour-tone of the plastic and the degree of saturation with the dyestuff used, and to the interconnection between these values and the light-fastness of the dyed surface. Experiments were conducted mainly with phenolics, and deterioration was shown to be accompanied by gradually increasing absorption for the blue; red-brown phenolics did not change appreciably on exposure to u.v. light. **Pigment-plasticizer combinations for cellulose lacquers** are described by van Eijnsbergen in "Chimie des Peintures," 1942/5/53. Titanium dioxide or chrome yellow were tested out with 15 different plasticizers or plasticizer mixtures; film hardness, adhesion, gloss and light-fastness were checked. Dichlorethylphosphate gave good results excepting with respect to hardness; tricresylphosphate raised adhesion, scratch hardness and normal hardness, but lowered gloss. Ethylacetanilide improved hardness generally, but diminished elasticity. **Effect of Plasticizers on P.V.C.** is discussed by Leilich in "Kolloid Zeit," 1942/99/107. Research was undertaken to determine the relationship between the viscosity of the plasticizer and that of the resulting mix, the relationship between the viscosity-temperature function of the plasticizer and the resistance to heat and cold of the mix, and between the viscosity of the mix and its electric conductivity. It is shown that the viscosity of the mix depends closely on that of the plasticizer, that the cold- and heat-resisting properties of a mix are, in general, good only for those plasticizers giving a flat viscosity-temperature curve, and that no simple electrical relationships can be drawn. **Combined trowel and hand fork** in plastic is illustrated in "Kunststoffe," 1942/32/92. It is pointed out that a moulding possesses ample strength to replace metal for this particular item. **Polymerization of styrene emulsions** forms subject of research by Yamamoto and Kawata reported in "J. Chem. Soc. Japan," 1940/43/350B.

Metallizing Plastics
(continued)

A Complete Survey and Critical Study of the Modern Methods of Metal Film Formation on Plastics for their Protection and Decoration

by E. E. HALLS

3. Metal Coatings Applied from Metal Wire, Powder or Liquid Using "Hot Pistols"

The processes under this heading are generally referred to simply as "metal spraying." Because of the soundness of both process involved and film obtained, efficiency, wide field of application and variety of purposes satisfied, metal spray processes are, perhaps, more completely entitled to be referred to as metallizing operations than any of the other procedures included in this survey. Over the last two decades the practical aspects of metal spraying have been afforded close attention by the commercial companies fostering the different types of process. In consequence, the present state of the art is based on sound foundations, working instructions are precise and accurate, and new users can adopt one or other of the processes with exact prior knowledge of the results, without misgivings or speculation. Such a state of affairs does not signify that the art of metal spraying has reached finality; quite the reverse is, in fact, the case, because development is always proceeding alongside routine application, not only for improvements and greater efficiency in the latter, but also for meeting new requirements and applications. Thus, for example, during the last five or ten years, notable advances in the wire spray method have included the following:—Nozzle sizes extended, enabling larger diameter wires to be used for larger surfaces with more rapid operating speed; practical details evolved for the use of butane or propane as alternatives to hydrogen or coal gas for the source of heat; and process extended to serve the purpose of building up worn tools or machine parts, or undersize components.

It is stressed at the outset that, although the metal spray processes are virtually hot processes, it is not necessary for the work to become unduly hot. Thus one can metal spray one's hand without discomfort from heat. It is a question of rate of passing the pistol over the work, or traversing the work past the pistol, that primarily determines temperature rise. Hence the first thought that often arises, to the effect that the processes cannot be applied to plastics, particularly to the thermoplastics, is incorrect.

Classification of Methods of Spraying

Methods of spraying with actual metal can be divided into three main groups, this classification being on the basis of whether the metal fed to the spraying apparatus is in the form of solid wire, solid powder or in bulk liquid. Each method uses a specially designed pistol or gun and commercial versions of these are available. They have been established in various applications over a period of many years and each can be regarded as quite sound. They are each applicable to a wide diversity of jobs, although, naturally, each has its merits and demerits and particular types of work for which more suitable.

The wire pistol is based on that originally developed for the Schoop process and is marketed by Metallisation, Ltd., who are authorities on the question of spraying metal from wire. The method can be applied virtually for any metal obtainable in wire form. Usually, the higher the melting point of the wire the smaller the diameter employed. Diameters of 1.0 and 1.5 mm. are the usual standards, but

larger sizes are also used. Again, the small diameters would be used when spraying small areas and the large diameters for large surfaces.

In the powder process the commercial gun has been developed by Schori, Ltd., and it is applicable to any metal that can be obtained in fine powder form. The liquid method uses a commercial gun developed by Mellowes, Ltd., and can be used for metals of which the melting point is not too high, excessively hot liquid metal naturally attacking the metal components of the gun and rendering its design and construction too difficult or impossible.

With the wire method it is usually the practice in coating a surface to use an interlacing technique traversing the gun in one direction across the surface of the work and then in the direction at right angles. As a guide it may be taken that the normal thickness of metal coating that can satisfactorily be produced in this manner is of the order of 0.004-0.005 in., although much thinner coatings can be obtained satisfactorily for specific purposes. With the liquid and powder methods a range of thicknesses is similarly practicable. In general, they are rather quicker than the wire method, although this is not necessarily the case in all applications. All methods are responsive to very precise control of thickness of coating despite the fact they are manually operated spray processes. Starting and stopping of the gun is easily controlled, particularly with the Schori process, so that the methods can be applied equally satisfactorily to very small articles as to very large ones. With the liquid method it is preferable to prepare as much of the work as possible and avoid start-stopping, because there is a tendency for the molten metal to freeze in the nozzle of the gun, and this has to be cleared before re-operating.

Preparation of Surfaces

Preparation of the work for metal coating is simple, and, in general, consists of cleaning and roughening. Obviously, all work must be free from oil and grease or any loose dirt, such as machining swarf, but, apart from that, the metal-sprayed particles will, in general, only key to roughened surfaces. This roughening can be produced by abrasive blasting, using sand, carborundum or angular steel shot by one of the orthodox processes. Shot-blasting is most usually employed, because of freedom from silicosis problems, and would be used not only for metal work but also in plastic mouldings and sheet materials, particularly those of the phenolic or amino resin types. There are exceptions and there are many instances where a thin lacquer or shellac coating is used to promote the adhesion. There are also cases where roughening preparation obviously is not required, for example, for the coating of textiles and textile-covered objects, that is, those in which the nature of the surface itself provides for mechanical interlocking. Coatings that are properly produced are

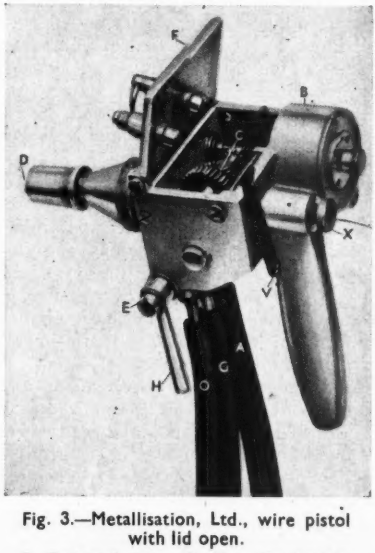


Fig. 3.—Metallisation, Ltd., wire pistol with lid open.

B.—Turbine chamber. C.—Hinged bracket. D.—Pistol nozzle. E.—Valve controlling gases. F.—Hinged lid. H.—Valve handle. V.—Spring lever, fastening the lid (F). X.—Opening for insertion of the wire. A.—Air supply tube. G.—Fuel gas supply tube. O.—Oxygen supply tube.

strongly adherent and the adherence is permanent.

In a broad sense the metal coatings retain the properties of the metals, particularly in the chemical and corrodibility senses. From the electrical conductivity point of view spray coatings are inferior to the solid metal in rolled or drawn forms, merely by virtue of their mode of formation, which renders them rather less dense than the solid metal. Further, there is the chance of slight superficial oxidation of each metal particle which may, in some cases, reduce the electrical conductivity.

Details of Equipment

Brief consideration is warranted to the equipment required and its mode of operation for each of the metal spray processes. Shot (or sand) blasting plant, common to them all, will not be included.

The wire process requires the metal spraying pistol itself, wire supply, oxygen and fuel gas, compressed air, and accessories in the way of valves, regulators and interconnecting rubber tubing. Gloves for handling hot work and protective masks may be desirable or insisted upon when spraying specific metal (e.g., lead). These last requirements will be common to all processes.

In the wire pistol, the metal to be sprayed is fed in the form of wire of uniform diameter from a reel or drum freely supported. This wire is carried through the pistol by means of a small air turbine, reduction gears and knurled gripping rolls, thus feeding it to the melting nozzle. At the latter, a flame is maintained by means of oxygen and compressed coal gas, hydrogen or other combustible gas, such as propane, butane or acetylene. The supply of these gases is accurately controlled by regulating valves and pressure gauges, the relative quantities being determined by the composition of the metal wire, its melting point and diameter. The metal, as fast as melted, is atomized by means of compressed air and carried forward on to the work, a distance of 3 to 5 ins. away. The wire pistol thus houses the turbine wire feed mechanism, the nozzle at which melting occurs, the feed system for compressed air to the turbine and for atomizing and propelling the spray, and the feed system for the oxygen and fuel gas. It is compact, well balanced, handleable and manipulable. Full details of the various gas pressures for each metal composition and diameter can be supplied by the makers.

On the Continent and in America wire pistols of closely similar construction are employed.

For dealing with inside surfaces of tubes or containers, either a rotary nozzle or an extension device can be used. Start-stop in all cases is controlled by the " on " or " off " of the compressed air.

As with paint and enamel spraying, a suitable hood and exhaust have to be provided when spraying in a confined space. This need only be of simple construction, and an expansion chamber can be incorporated for separating and recovering as scrap much of the metal dust.

The outstanding difference with the Schori powder pistol is in the method of feed to the hot nozzle. The powder is fed from a reservoir by injector principle into the gun. Start-stop is controlled by the thumb of the hand holding the pistol covering or uncovering an orifice.

The Mellowes liquid metal pistol, like the powder gun, has no moving parts for feeding the metal. The molten metal is ladled into the malleable-iron container of the gun and maintained there at the correct temperature by means of a burner which is an integral part of the gun and which operates with compressed-air injection on the Bunsen principle. The life of the container is limited to a few weeks of continuous operating. The air supply to the nozzle is preheated by passage through a tubular coil in the sphere of influence of the burner. The nozzle is of silver steel, its life being limited to something of the order of ½ to 2 hours.

Several models of the Mellowes gun are available, the standard type, a small form for intricate work, one for upward spray for overhead work, and a modification of the standard for taking care of alu-

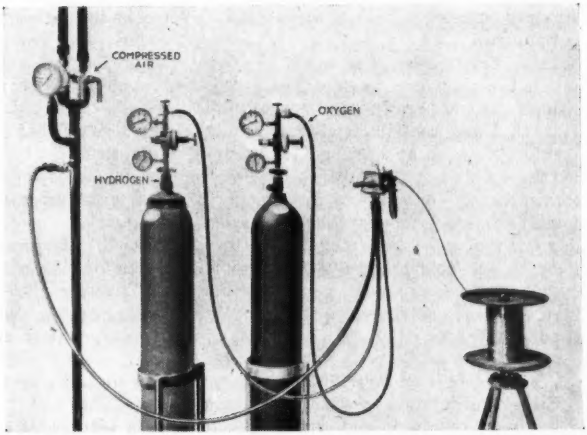


Fig. 4.—Oxy-hydrogen metal-spraying installation for the "Metallisation" pistol.

minium, in this case the handle being air cooled and the protecting cowl being of heat-resisting alloy and designed to give more uniform and intense heating of the container.

It is to be noted that the three types of gun referred to are commercial tools, established on their merits in industry. Although it is unfair to compare them since local circumstances play some role in assessing suitability, it is felt that some guide must be given, and if the comparison is taken in the spirit that it represents an individual's view from, perhaps, a restricted field, then it is justified.

It is considered that the wire pistol represents a metal spraying tool that most closely approaches universality of application. It is light in weight, easily fed with metal to be sprayed, easily disassembled and re-assembled. Operators can be quickly trained in its manipulation. Wearing parts, gears and nozzles are easily replaced. It is suitable even for high-temperature melting point metals, including the irons and steels and nickel.

The powder pistol closely approaches the wire pistol in universality, its only further restriction being the possibility in obtaining the metal in powder form. Incidentally, it has been used for spraying non-metals of plastic nature, such as bitumen, shellac and rubber.

The liquid metal spray gun is regarded as a somewhat cruder tool, requiring more frequent replacements. It is limited to the lower melting point metals, with aluminium (M.Pt. 658 degrees C., spraying temperature about 700 degrees C.).

Other liquid spray guns are used. For the fusible alloys of melting point 60 to 110 degrees C., e.g., Wood's metal, some works adapt an ordinary paint spray gun by winding an electrical element around the container. This is only an improvisation, and difficulties arise in temperature control, nozzle wear and spray adjustment. Specially constructed electrically heated guns are also used for low melting point metals. One of these is very efficiently constructed. The metal chamber is of steel, heated by means of an electrical winding. Inner and outer nozzles are properly designed and made in tool steel, case-hardened. The steel needle valve has carefully constructed finger-operated trigger with three successive movements controlled to accurate dimensional limits. These are, first, "take-up" the slack and apply finger pressure; secondly, to open the air flow; and, thirdly, the metal flow. The air flow tube is also electrically heated. Wear and tear involves periodic replacement of inner and outer nozzles. The gun is rapid, of similar order to the Mellowes,

has heated pistol. For fusible alloy of melting point about 100 degrees C., a molten metal temperature of 150 degrees C. is suitable and an air pressure of 10 to 12 lb./sq. in.

One of the most useful surveys of metal spraying in recent years was by E. C. Rollason, "Metal Spraying: Processes and Some Characteristics of the Deposits," published in the Journ. of Inst. of Metals, 1937, 50, 1, p. 35. This deals in a fundamental and critical manner with many aspects of metal spraying that are applicable to problems appertaining to plastics equally as well as to metals. It is worthy of study by those interested in the art of metal spraying. The information given in Table 8 is reproduced from this article. It concisely summarizes in a general way the main features of the three types of metal spray pistol. From this tabular presentation, comparison can easily be made.

Among the metals commonly sprayed industrially on plastics are the following:—

Tin and fusible alloys for electrical contact or electrical conductivity.

Lead for X-ray screens.

Zinc for electrical shielding or earthing.

Aluminium for electrical shielding or earthing when a non-corrodible coating is required, zinc tending to whiten under severely corrosive conditions.

Copper for magnetic and electrical screening, including radio frequency applications.

Brass for electro-magnetic screening.

It is stressed that the compressed-air supply must be free from oil, because, apart from any adverse influence upon the sprayed coating, it may be filtered out at the nozzle, and an accumulation there may cause an explosion of more or less violent nature.

The suppliers of the respective guns

Table 8.—Comparative Details of Three Types of Pistols (makers' figures).

	British wire	Molten metal	Powder
Valves	Single-plug type inside casing	Only taps on the Bunsen burner	Finger control for powder; separate valves for the gases
Moving parts ..	Turbine and gears encased	None	None
Weight	3½ lb.	6½ lb.	2¾ lb.
Metal form ..	1, 1½, 2 mm. dia. wires	Ingots melted in furnace	Powder; zinc, 100; copper and aluminium, 150; nickel, 200 mesh per in.
Limiting melting point	1,550°C.	600°C. (aluminium-silicon alloy)	1,550°C. (copper highest in England)
Speed of application for zinc	5 lb./hr.; 17 ft.²/hr. (0.005 in.). 11.9 lb./hr. using 2 mm. wire	16 lb./hr. including stopping	20 lb./hr.
Wastage	10–20%	10–20%	20–30%
Oxygen	30–40 ft.³/hr.; 25 lb./in.²	None used	50 ft.³/hr.; 14–28 lb./in.²
Combustile gases	Coal-gas, 45 ft.³/hr.; 28 lb./in.²; or acetylene 24 ft.³/hr.; 10 lb./in.²	Coal-gas, 40–75 ft.³/hr. at town main pressure; gas for furnace 150 ft.³/hr. for 3 pistols	Enriched coal-gas (ferrolene) 75 lb./in.²; acetylene 43 ft.³/hr.; 3 lb./in.²
Air	15 ft.³/min.; 45 lb./in.²	15 ft.³/min.; 65–75 lb./in.²	15 ft.³/min.; 43 lb./in.²
Normal working distance	3 in.	5 in.	10–12 in.
Internal work ..	1–3 in. dia., use rotary nozzle; 3–12 in. dia., use extension and deflector nozzles	Shallow work only	Shallow work
Overhead work	No difficulty	Impossible	No difficulty

Fig. 5.—The Schori pistol.

issue brochures with recommendations and operating instructions. From these, the appended illustrations of guns have been taken. Fig. 3 shows the wire pistol, Metallisation, Ltd., and Fig. 4 shows the complete equipment required using oxygen/hydrogen with this pistol. Fig. 5 shows the powder gun of Schori Metallising Processes, Ltd. It illustrates its handleability and clearly shows the thumb-controlled aperture for the " off " and " on " of the metal powder. Fig. 6 shows the construction of the Mellowes Co.'s liquid metal spray gun.

To appreciate the structure of a sprayed metal coating, brief consideration of its mode of formation is helpful. With proper atomization, the metal spray leaves the nozzle of the gun in small liquid particles approximately spherical in shape. These spherical particles undergo some distortion during their passage through space to the material upon which they are deposited. The degree of distortion is dependent upon the speed of the particle and the distance, as well as upon the nature of the metal and its temperature, or the extent to which it is above its melting point. It is speculated that the particle shape becomes elongated in the direction of travel with a tendency to pear-shape. Particles solidifying during travel, upon impact with the material upon which deposited, flatten and tend to become saucer-shaped. These key into the roughness of the base material and, as the coating builds up, interlock with one another, providing adhesion. Particles striking the surface normally will be circular in the cross-section parallel to the surface of the material; those striking obliquely may become more or less elongated, egg or pear shaped. If the metal particles are not solidified at the time of impact, they may splash. This would occur if the metal is too hot or if the distance of the gun from the work is too small. It is an undesirable feature, as it would favour neither uniformity of the film nor maximum adhesion. Fig. 7 is a microphotograph by transmitted light at a magnification of 18 of a fusible alloy sprayed on transparent mica from a liquid metal pistol. The coating has not been built up sufficiently to give a continuous film with particles linking together, and thus the shape of the particles is clearly defined. They are relatively uniform and more or less elongated. Fig. 8 is a

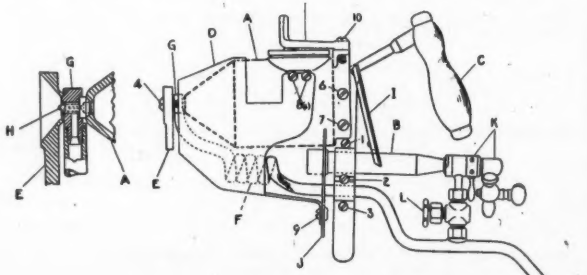


Fig. 6.—Mellowes Co.'s liquid spray gun.
A.—Container. B.—Burner. D.—Cowl. F.—Compressed air coil. G.—Air feed. H.—Nozzle. K.—Air and gas injector. L.—Air regulator.

similar microphotograph. The particles are rather larger and more clustered, but the elongated shape is clear.

From the nature of the mode of build up of a metal-sprayed coating, already briefly indicated, it is evident that the metal coating, as compared with rolled, drawn, extruded or even with cast metal, must be porous. There must exist cavities and even air pockets which the metal spraying process itself cannot eliminate. The density of sprayed metal is, therefore, always less than that of the same solid metal, and the extent of lower density is a function of all the variables

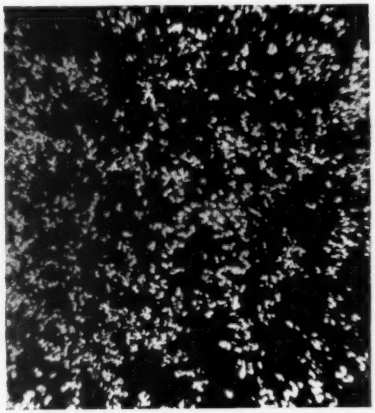


Fig. 7.—Micrograph (× 18) of fusible alloy sprayed from "liquid" pistol on mica, taken in transmitted light. Note elongated rounded particles.

obtaining, viz., particular spray method, particular metal sprayed, nozzle size, air pressure, distance between nozzle and work, temperature of metal upon leaving the nozzle and at arrival at the work surface, and upon the thickness of coating built up. A thinner coating would be expected to show greater porosity than a thicker film of the same metal. A light metal would be expected to reveal a larger percentage drop in density than a heavy metal sprayed to the same linear thickness of film. All these facts are borne out in general practice.

This shortcoming with respect to density has its direct influences upon physical, mechanical and electrical properties. In the latter respect particularly is it necessary to observe the low density of sprayed coatings. But apart from increased electrical resistance, or reduced conductance resulting from this one factor alone, electrical properties may be influenced by oxide inclusions. This oxidation can occur at the nozzle during the projection of the hot metal particles to the work, and on the work surface before cooling off. In the powder process the particles may be appreciably oxidized at the outset. Further, during spraying, the cone of atomized spray travelling at high velocity will tend to draw air from behind the nozzle on the injection prin-

Fig. 8.—As Fig. 7, except that the sprayed metal particles are larger.

ciple, and this will especially tend to oxidize the outer layers of metal in the cone spray. Rollason's remarks upon oxidization are of especial interest and the section on this subject is extracted from his paper, viz.:—

"Oxide Content of Sprayed Coatings.

"In the literature on this subject there are many different opinions regarding the oxide content of the sprayed deposit. Schoop (Handbuch der Metallspritz - Technik, 1935), Arnold (Z. anorg. chem., 1917, 1, 209), Bablik (Korrosion u. Metallschutz, 1925, 1, 126-129) consider that no oxi-

dation of the particles in flight occurs except when a highly oxidizing flame is employed. Reininger (Z. Metallkunde, 1933, 25, 42-44, 71-73, 286-288), Parker (Korrosion u. Metallschutz, 1926, 2, 266-269), and Karg (Korrosion u. Metallschutz, 1927, 3, 110-112, and Z. ges. Giesserei-Praxis: Das Metall, 1927, 48, 1-2) admit the presence of oxide in the coating, but no values are given. The estimation of oxygen in most metals offers experimental difficulties with the exception of copper. A few typical values for copper are given in Table 9, while data from a paper by Ballard and Harris (12th Internat. Congr. Acet. Welding and Allies Ind., 1936) for copper coatings from the wire pistol are given in Table 10.

" These investigators also show that the oxygen content of the coating is (a) increased as the oxygen pressure is increased, and (b) reduced by keeping the base metal cool. This is not unexpected, since the oxidation of the metal occurs (1) in melting, (2) during flight, and (3) on the surface of the article. At close distances the particles are in a reducing zone of the flame, thereby being protected from oxidation in flight. To obtain deposits low in oxide, it would appear advisable to use a slightly reducing flame and to reduce the nozzle distance so far as it is possible without overheating the base. Unfortunately, a pistol using a reducing flame is not working at its maximum efficiency. The practice of preheating the article advocated some 10 years ago is now seen to be undesirable.

" In one German pistol (E. Waser, Chem. Zeit., 1928, 52, 719-721) carbon dioxide is used for atomizing in the case of low melting point metals, and the use of nitrogen instead of air has also been suggested but not worked commercially."

The values given in Table 9 indicate that coatings from the powder pistol may show considerably more oxidation than those from the wire gun. In fact, the oxygen content expressed as cuprous oxide is of the order of 30 per cent., quite a high order that cannot easily be ignored. The wire pistol values are generally less than half this, especially when acetylene is used as fuel gas, in which case they only reach one quarter to one sixth of the percentages given for the powder method. The oxygen values are further confirmed by the data given in Table 10.

Other test results appertaining to density and electrical conductivity measurements upon metal coatings applied to plastics by the wire pistol method are of interest. For copper and aluminium, 1.0 mm. dia. wire was employed, while for lead 1.5 mm. dia. was used.

Table 9.—Oxygen in Sprayed Metal Coatings (Copper).

	Nozzle distance, inches	Oxygen, per cent.	Cu_2O, per cent.
Powder Pistol ..	8	2.84	25.6
Powder Pistol ..	10	3.39	30.6
Powder Pistol ..	12	3.17	28.4
American Wire ..	3	1.72	15.4
English Wire ..	3 C.G.	1.02	9.2
English Wire ..	3 Ac	0.59	5.3
French Wire ..	3 Ac	0.71	6.4

C.G.=Coal Gas. Ac=Acetylene.

Table 10.—Percentage of Oxygen in Copper Deposits (Ballard and Harris).

Nozzle distance, inches	Coal-gas Fuel (450 B.T.U.)		Acetylene Fuel Gas		
	English	French	English	French	American
1	0.79	0.35	0.32	0.33	—
2	0.80	0.40	0.56	0.46	0.74
3	0.90	0.54	0.54	0.65	0.90
4	0.10	0.60	0.61	0.76	1.03
5	1.15	0.69	0.69	0.75	1.12
6	1.08	0.66	0.66	0.72	1.04
7	0.95	—	—	—	1.06
8	0.91	—	—	—	1.27
9	0.75	—	—	—	—

English pistol designed for coal-gas.
French pistol designed for acetylene.

Table 11.—Characteristics of Copper Metal Sprayed Coatings (Wire Pistol Method) on Phenolic Paper Laminated Sheet. Thickness, Electrical Resistance and Specific Gravity.

	Sample No.	
	1	2
Thickness in inches, measured by micrometer, average	0.0060	0.0052
Thickness in inches, calculated from weight determination and specific gravity value of 8.9	0.0034	0.0029
Specific gravity of coating from measured thickness and weight	5.05	4.95
Ratio of density of copper metal sprayed coating to that of solid copper	0.57	0.55
Electrical resistance, measured in ohms	0.00850	0.00940
Electrical resistance of solid copper of equivalent measured dimensions	0.00100	0.00115
Ratio of electrical conductivity of copper metal sprayed coating to that of solid copper	0.12	0.12

Table 11 refers to copper metal sprayed on to phenolic laminated paper sheet by the wire process and the coatings then examined for density and electrical conductivity. The electrical measurements were made by millivolt drop method. The tabulated results are self-explanatory and it will be seen that the density of the sprayed layer is approximately only two-thirds of that of solid, cast, drawn or rolled copper, and that the electrical conductivity is only about 10 per cent. of copper in these last forms. The lower density almost entirely, if not completely, accounts for this poorer conductivity. Nevertheless, for most purposes this conductivity value is satisfactory.

Table 12 similarly applies to aluminium metal sprayed by wire process. It shows the same extent of lower density and conductivity.

Table 13 appertains to lead sprayed by wire pistol. In this case only density figures were taken. The characteristic tendency to low density is again apparent. With the thinner coatings the density is only about three-quarters of that of the solid metal, but it rises higher with the thickest coating. Here, again, such lead coatings can be quite satisfactory for specific applications, such as electrical screening in X-ray work. In this application the thickness of lead coating applied naturally has to depend on the electrical conditions obtaining, but thicknesses from .005 to .010 in. have been used.

In carrying out these tests, an outstand-

Table 12.—Characteristics of Aluminium Metal Sprayed Coatings (Wire Pistol Method) on Phenolic Paper Laminated Sheet. Thickness, Electrical Resistance and Specific Gravity.

	Sample No.	
	1	2
Thickness in inches, measured by micrometer, average	0.0040	0.0055
Thickness in inches, calculated from weight determination and specific gravity value of 2.7	0.0023	0.0032
Specific gravity of coating from measured thickness and weight	1.56	1.56
Ratio of density of aluminium metal sprayed coating to that of solid aluminium	0.58	0.58
Electrical resistance, measured in ohms	0.02160	0.02040
Electrical resistance of solid aluminium of equivalent measured dimensions	0.00246	0.00171
Ratio of electrical conductivity of aluminium metal sprayed coating to that of solid aluminium	0.110	0.085

Table 13.—Characteristics of Lead Metal Sprayed Coatings (Wire Pistol Method) on Phenolic Paper Laminated Sheet. Thickness and Specific Gravity.

	Sample No.		
	1	2	3
Thickness in inches, measured by micrometer, average	0.0018	0.0048	0.0089
Thickness in terms of weight, by chemical estimation, expressed in mgms./sq. inch, average..	256	618	1,440
Thickness of coating in inches, calculated from weight determination and specific gravity value of 11.35	0.0014	0.0034	0.0080
Specific gravity of coating from measured thickness and weight	8.8	8.1	10.2
Ratio of density of lead metal sprayed coating to that of solid lead	0.78	0.71	0.90

ing feature that impressed itself over a range of samples was uniformity, this referring to thickness, density and electrical conductivity. With the lead coatings, the smaller loss in density of this higher density metal is to be observed, as well as its approach to the solid lead value in the thickest coating.

Spraying for Electro-magnetic Purposes

The use of metal-sprayed coatings of copper or brass has proved effective for electromagnetic screening purposes and has simplified assembly operations by eliminating the need for fixing screens of sheet metal. Complications from soldering, seam welding, riveting, and other methods of fixing have thus been avoided. Space difficulties, likewise, are eliminated, and, moreover, a sprayed screen can be applied exactly where required with very little practical trouble. However, perhaps one of its most important fields is for high-frequency screening or conductance. Structures, cabinet work and sheet-metal panels in aluminium or light alloy yielded sufficient surface conductivity, but these light alloys have had to be substituted. Where steel has been utilized, copper spray coatings applied by the wire process in thicknesses of the order of 0.005 in. have proved successful in giving superficial conductivity despite their relatively low electrical conductance values. Steel, however, often has other objections, weight being an important one and magnetic properties another. The logical substitute is a plastic material with phenolic resin base plastics the basis as a general-purpose product. Electrical grades of synthetic resin bonded paper or fabric sheet serves most panel requirements excellently, while various grades of phenolic moulding powder, particularly the higher qualities of shock-resisting materials, are apt choices for the many box-like components of radio transmitting and receiving equipments. The phenolic resin panels are being exploited, but not much progress seems to have been made with the larger components in moulded form. Such articles need a metal surface on one or both surfaces, usually with certain areas masked. Under high-frequency conditions, it does not follow that copper is necessarily the best metal for this application, although the general indications are that electrical conductivity as ordinarily measured is a sound guide, that is, the order of merit of the various metals is given by arranging them in descending order of specific conductivity or ascending order of specific resistance. To obtain a numerical evaluation by direct high-frequency measurements is not simple, first, because of difficulties associated with the measurements themselves, secondly, on account of variables in producing the metal coatings, and, thirdly, because of the peculiarities associated with each particular job. In general, tests are usually made by practical trials in relation to specific jobs. However, some standardized tests are made, and some results are presented on this basis. These were made on test pieces 1½ ins. square, the material being

a high grade of phenolic paper laminated. Test pieces were metal sprayed one side or both sides, several metals and several thicknesses of it being examined. The measurement was obtained by means of a Q-meter, placing the test piece in series with a standard coil. The contacts to the test pieces were by screw, nut and washers fixed through the specimen at the extremities of a diagonal. The measurements were made at several frequencies, viz., at 5, 7 and 20 megacycles. The merits of the metal-sprayed coatings were assessed in a comparative manner by the loss in Q value, the more efficient coatings causing the least fall in this quantity. Values are given for coatings applied by means of the wire pistol in Table 14 and from the powder pistol in Table 15. There are evident inconsistencies in the tabulated data that indicate that the results should only be used as a broad guide. Thus it would seem quite definite from Table 14 that copper as a sprayed coating is somewhat superior to aluminium and definitely superior to zinc. These are facts that would be anticipated from specific conductivity values. Samples 1 and 2 show little difference in performance between a normal wire spray coating of 0.004 to 0.006 in. and a heavy coating of 0.012 in., again to be anticipated since surface conductivity is the quality in question. Samples 3 and 4 show up a little better at the medium frequency and worse at the highest frequency. No. 3 being a very thin coating both sides could account for this, but No. 4 is a normal thickness on both sides and cannot be explained. However, all the coppers are good, and it may be the test was not discriminating enough for the actual test figures to have precise significance. With the aluminiums, sprayed on one surface only, the thick coating No. 6 is superior to the thin one No. 5, but the rather thinner coatings sprayed both sides are better and, compared with one another, are of equal merit. These two-sided aluminium spray coatings compare favourably with copper. With the zinc coatings, applied one one side, the normal thick coating (0.006 in.) is superior to the thin one. With the comparatively thinner zinc coatings sprayed on both sides, again the thicker coating is better, in fact, markedly better than any of the zinc specimens. Again, a generality can be stated to the effect that loss in Q value is less at the highest frequencies.

Table 14.—Various Metal Spray Coatings (Wire Pistol Method) on Phenolic Laminated. Thickness, Density and Electrical Test Results.

Sample No.	Metal sprayed	Total thickness of coating (one or two surfaces), average			Relative density	Fall in Q value at megacycles		
		Mgms./ sq. in.	Inches (calculated)	Inches (measured)		5	7	20
1	Copper on one surface ..	320	0.0022	0.0055	0.40	4	8	1
2	Copper on one surface ..	1,000	0.0071	0.0125	0.57	3	9	1
3	Copper on both surfaces ..	220	0.0015	0.0040	0.38	4	4	6
4	Copper on both surfaces ..	610	0.0043	0.0092	0.47	5	4	4
5	Aluminium on one surface..	80	0.0017	0.0036	0.48	6	9	13
6	Aluminium on one surface..	240	0.0053	0.0096	0.55	4	8	7
7	Aluminium on both surfaces	45	0.00095	0.0021	0.45	5	5	4
8	Aluminium on both surfaces	150	0.0032	0.0058	0.55	5	5	4
9	Zinc on one surface	130	0.0011	0.0032	0.35	12	6	4
10	Zinc on one surface	390	0.0033	0.0064	0.52	7	6	2
11	Zinc on both surfaces ..	120	0.0010	0.0021	0.48	10	7	5
12	Zinc on both surfaces ..	280	0.0023	0.0040	0.58	4	7	2

Table 15.—Various Metal Spray Coatings (Powder Pistol Method) on Phenolic Laminated. Thickness, Density and Electrical Test Results.

Sample No.	Metal sprayed	Total thickness of coating (one or two surfaces), average			Relative density	Fall in Q value at megacycles		
		Mgms./ sq. in.	Inches (calculated)	Inches (measured)		5	7	20
1	Copper on both surfaces ..	320	0.0022	0.0046	0.48	10	12	28
2	Copper on both surfaces ..	240	0.0017	0.0040	0.43	9	14	50
3	Aluminium on one surface..	220	0.0047	0.0070	0.67	11	14	60
4	Zinc on both surfaces ..	500	0.0042	0.0072	0.58	4	8	24
5	Zinc on both surfaces ..	850	0.0071	0.0110	0.65	3	6	23

Studying the values from the powder spray method in Table 15, it is seen that copper (samples 1 and 2) does not show up at all well; it is very poor compared with the wire method. This may be due to oxidation of the original copper particles. Aluminium is poor, and zinc is poor except at the lowest frequency. For all the specimens, the loss in Q at the highest frequency is extraordinarily high, a phenomenon in strong contrast with that observed with the wire-sprayed coatings.

Whatever limitations may attend the interpretation of the test values at high frequencies, the important fact is established by them that sprayed metal coatings do efficiently perform the function required of them under these specific electrical conditions. Further, they confirm that copper from the wire pistol can be confidently relied upon, they show that alternative metals are possible, and that nothing out of the ordinary is required with respect to thickness, the best value of which can readily be settled by trial or experimentation.

(To be continued)

BRITISH STANDARD SPECIFICATIONS

War-time Rubber and Insulated Cables

A new type of cable, known as the P.V.C. cable, has recently been developed as a substitute for rubber-insulated cables. The insulating compound is polyvinyl chloride, and although this material has been used as a cable dielectric for special purposes for some years, its use on the large scale has hitherto been restricted by the availability of supplies. During recent months the production of polyvinyl chloride has been substantially increased. To meet this situation a supplement to B.S. 7, Rubber-insulated Cables, has been issued by the British Standards Institution. Included in the same document are a number of amendments to the specification for rubber-insulated cables. The amendments and the supplement are contained in the document P.D. 118, copies of which may be obtained from the British Standards Institution, 28, Victoria Street, London, S.W.1, price 2s. post free.

Emergency Colour Card

The British Standards Institution has just issued a war emergency revision of B.S. 381C—Standard Colours for Paints. The reduced range has been prepared with a view to ensuring economy in paint materials and there are three groups of colours. The first group includes colours for paints for general purposes and there are eighteen colours in the group. The second group includes colours which have had to be retained because they are specified by one Department or another for identification purposes. The third group includes five colours which are required for the painting of public service vehicles. No new colours have been introduced and the colours in the three groups have all been selected from the range covered by B.S. 381. Copies are obtainable from the British Standards Institution, 28, Victoria Street, London, S.W.1.

Sheet Plastics Seamed by Radio Current

DIFFICULTIES encountered in the making of seams when putting together sections of patterns of sheet thermoplastics in mass production are believed to have been overcome by a "radio sewing machine" developed experimentally by the RCA Laboratories, at Princeton, New Jersey, U.S.A.

There is a definite need in the plastics industry for a satisfactory means of making seams in plastic fabrics used in the manufacture of raincoats and caps, packaging foods and oils, and making small balloons for atmospheric soundings in weather forecasting. Usual methods of seaming are by sewing with thread, cementing, and fusing with externally applied heat. The last is the most desirable method but involves problems of maintaining uniform temperature and the processing equipment becomes sticky with plastic material. None of these methods is entirely satisfactory.

The device developed under supervision of Dr. G. H. Brown, research chemist of the RCA Laboratories, surmounts the difficulties of making fusion seams by utilizing electronics to heat the plastic internally. The bond created is said to result in a continuous seam that is water- and air-tight and stronger than the sheet material itself.

This new seamer has two small roller wheels between which the overlapping edges of the material to be united are fed. These wheels draw the material along between them in the manner of the foot and feeder of a sewing machine, and at the same time serve as plates to create a small electromagnetic field of radio-frequency current that passes through the material. Resistance of the atoms in the plastic to passage of the current generates heat by di-electric loss, causing the plastic to soften and fuse together in a tight weld or bond.

The operating current is derived from a radio-electronic oscillator of low power, and a small electric motor operating on 110-volt alternating current drives the roller wheels. Starting, stopping and speed are controlled by a pedal.

Although the present model is only experimental, it is being tested under actual working conditions in the plant of a large manufacturer to ascertain the best design for commercial operations. In the meantime, the RCA Laboratories are developing other methods of applying the same general principle to fabricating thermoplastics, as, for instance, using specially arranged electrodes in presses to seal packages in a single, quick operation.

INQUIRIES AND ANSWERS

(In Which is Included General Correspondence)

IMPORTANT NOTICE: If inquirers wish to receive replies by post, a stamped and addressed envelope must be included in their letter. Unless otherwise stipulated, it is understood that the submission of a problem to the Editor permits its publication in this journal.

Bonding Rubber to Steel

In order to assist us with various experiments we are making, we should greatly appreciate any information you may be able to give us regarding cementing thin sheet-steel plates on to steel by means of either rubber or plastic cements.

F., LTD.

[EDITOR'S NOTE: The subject of rubber bonding cannot be discussed in a short note, but we hope to publish an extensive article on the subject at some future date. With regard to the adhesion of rubber, the inquirers doubtless know of the well-known rubber-brass-steel technique and the interesting modern research that is being carried out on the possible effect of the position of sulphur in the rubber molecule in its relation to the brass interface.

Another technique which has assumed importance is that of bonding rubber to steel with a special organic adhesive. While the general idea is old the newer cements give excellent results, the methods adopted by, for example, Reliance Rubber Co., Ltd., give sheer strengths of 1,000 lb. per sq. in. This is important in view of the present difficulties of the plating industry.

The use of thermosetting plastics for metal-to-metal joints was described in "Plastics," May, 1943, p. 216.]

Plastic Wheels

As we can no longer supply our customers with rubber-tyred wheels, and cast-iron wheels being unsatisfactory in some cases, we are looking for a suitable substitute and wonder whether you are making plastic wheels for a diameter of between 4 ins. and 8 ins., and a carrying capacity of up to 3 cwts. each; they are to be fitted only on hand-operated trucks, and, if necessary, can be fitted by us with roller bearings.

We should be glad if you could put us in touch with a likely manufacturer.

Newcastle. T.T. AND T. CO., LTD.

[EDITOR'S NOTE: Excellent wheels for trolleys were made from laminated fabric impregnated materials and also, we believe, by compression from special shock-resisting resins. Information is available from most resin manufacturers.]

Heat-resisting Plastics

Within the very near future it is highly probable that we shall require small moulded bases in sizes approximately 2 cubic ins. each. They are to be used in conjunction with certain electrical equipment, and will have to work under conditions whereby the temperature may be as high as 500 degrees F.

We have been advised in a rather roundabout way that phenolic resin moulding would most probably be the most suitable at this high temperature.

Leicester. I.L.B. AND CO., LTD.

[EDITOR'S NOTE: No commercial plastic compound will stand up to 500 degrees F. The upper limit of heat resistance of the asbestos or other mineral filled phenolics is about 450 degrees F. High temperature resistance is claimed for the new silicone resins by British Thomson Houston, but we do not know exact figures nor whether the production stage has yet been reached.]

Plastic Trays

Referring to the inquiry from B. and Co., Ltd., regarding plastic trays, in the July issue, we have in the past produced laminated fabric moulded trays in Tufnol which will withstand a normal working temperature of 100 degrees C. for continued periods.

With regard to possible contamination of food products, this depends to a certain extent upon the foods, but we would mention as a matter of interest that Tufnol bearings and stop-cocks have been used with success in tomato-juice and ketchup equipment.

We are able to offer one or two types of tray from existing moulds, and it is possible that these could be adapted to the purpose in question.

ELLISON INSULATIONS, LTD.

The Limitations of Plastics

Following a demand by many engineers, the author classifies the best-known plastics, their mode of fabrication and strength characteristics

By
D. Warburton Brown, A.M.I.A.E.

AT present it is very much the fashion in the plastics industry to decry speculation as to the possible future role of plastic materials in our national life. There is certainly a good deal of justification for this attitude, for speculation, not only by non-technical persons, had become thoroughly out of hand, and had led to a widespread misunderstanding as to the present position of plastics. The result of this undesirable publicity has been that a number of uninformed persons has submitted problems to the manufacturers of plastics and, on being told that their proposals are unsuitable for plastics, have gone away with the feeling that plastics have been "boosted" by false propaganda. The inferences are obvious, and such ideas can be only detrimental to the industry as a whole. To counter this the industry has very wisely inaugurated a campaign to bring the real position before the public and before potential consumers.

It is suggested that the most effective method of dealing with the position is not to decry all speculation, because this, even from the layman, is conducive to development and research. Take away speculation and development stagnates. By far the best method of countering dangerous speculation is to drum home to potential consumers and the public the position which plastics occupy now. Once this has been achieved, more reasonable suggestions will be forthcoming from customers and, in addition, there will be the feeling that the industry is doing its best to help and the mutual benefit will be helpful to all.

In this article the author proposes to examine under various broad headings the limitations of plastics as they stand to-day, and it is hoped that these brief notes will be helpful in bringing about a more satisfactory understanding of plastics by those outside the industry.

Table 1.—Available Plastics

Thermoplastics	Thermosetting
Cellulose Acetate	Phenol-formaldehyde
Cellulose Nitrate	Phenol-furfural
Cellulose Acetobutyrate	Urea-formaldehyde
Casein	Melamine-formaldehyde
Ethyl Cellulose	—
Methyl Methacrylate	—
Polystyrene	—
Polyvinyl Chloride	—
Polyvinyl Acetate	—
Vinyledene Chloride	—
Nylon	—

Note: The above lists are not complete, but give an indication of the more important materials.

Forms Available

To one unfamiliar with the subject, it is necessary first to appreciate the forms in which plastics are available. All plastics are sub-divided into two main groups:—

(1) Thermoplastic.
(2) Thermosetting.

The difference between the two is really self-evident from the terminology. The thermoplastics all soften with the application of heat and harden again upon cooling. The second group do not follow a reversible heat cycle, however. Upon heating they first soften and become plastic. The further application

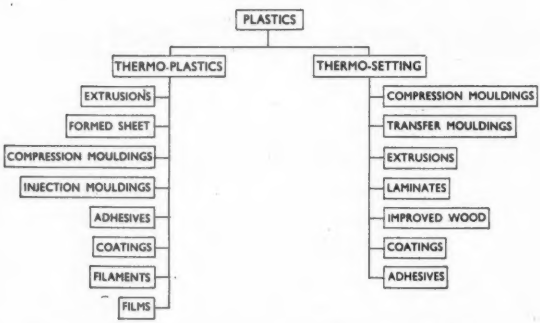


Fig. 1.—Chart illustrating fabricated forms in which plastics are available.

of heat causes them to set into hard, infusible solids upon which heat has little or no further action.

Each of the groups mentioned are available in a number of different forms (see Fig. 1).

Compression Moulding of Thermoplastics

Dealing first with the thermoplastic group: Compression moulding consists of placing the new material into a mould and subjecting it to heat and pressure. Under the action of these two agencies the plastic flows and takes the form of the mould cavity. Being thermoplastic it is necessary to cool the mould before ejecting the moulding. Only a small percentage of the thermoplastic products are made by this method.

Injection Moulding of Thermoplastic

By far the majority of thermoplastic mouldings are made by this method, which consists of feeding the powdered raw material from a hopper to heated chamber. Referring to Fig. 2, the raw material is placed in the hopper (A), whence it falls into the heated chamber (B). A piston (C) moving in the chamber (B) forces the plastic along the heated portion of the chamber to the mould (D). In this connection it should be noted that the temperature of D is lower than that of B, so that when the material flows into the mould cavities along the mould "gate" or channels it solidifies. The operation is extremely rapid, as the cycle takes under half a minute and multiple impression moulds are used. Where large quantities of articles are required this method of production is extremely suitable. A further advantage of this system is that the ejected mouldings require very little hand finishing, as is required when compression moulding is used.

Extrusion of Thermoplastics

The process of extrusion is very similar to that of injection moulding. Material is fed from a hopper into a heated chamber and forced through the extrusion nozzle,

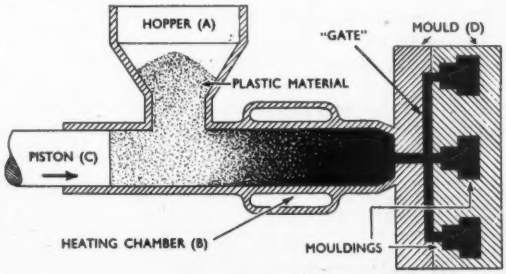


Fig. 2.—Principles of injection moulding.

which takes the place of the mould in Fig. 2. A very wide variety of forms can be produced in this manner.

Whilst on the subject of extrusion, mention must be made of the extrusion of cable covers. Various types of cable are now produced having the covering extruded in flexible, abrasion-resisting thermoplastics. Typical examples are shown in Fig. 3.

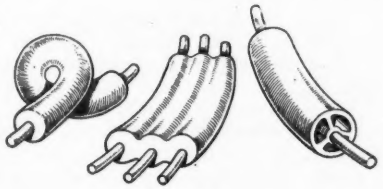


Fig. 3.

Sometimes thermoplastics are extruded over cord and the resultant product woven to form various articles—examples of which are seating and ladies' handbags. The wide variety of bright colours in which plastics are obtainable are useful in this sphere.

Forming of Thermoplastics

Many articles can be produced in thermoplastic materials without the use of complicated and expensive steel moulds. Sheets of the thermoplastic material are heated in an oven until they have become plastic. They are then removed from the oven and pressed by hand over a wooden or plaster former. Quite complicated articles can be made in this manner when used in conjunction with various types of cements. Typical of this type of work is the manufacture of the various types of transparent enclosures used on aircraft.

Coatings and Adhesives

The weather-resistant properties of plastics is put to useful purpose in the manufacture of coatings and adhesives. The protection afforded by these synthetic coatings—not only to weathering but also to acids and alkalis—is utilized to a large extent by the chemical industry for lining vats and other vessels for holding corrosive liquids.

Many of the thermoplastics provide excellent adhesives and these are used by the "safety" glass and plywood industries. In the latter—particularly in the manufacture of "densified" wood—the resistance of the plastic adhesives to attack by moisture and fungi marks a great improvement over the animal glues used previously.

Film and Filaments

Plastics, particularly cellulose acetate, are used largely in the production of photographic films. In the form of films the vinyl plastics also find an outlet for binding tapes for electric coils.

Nylon, a thermoplastic which has caught the imagination of the public, can be produced in the form of fine filaments only a few thousandths of an inch in diameter and possessing exceptional strength. In this form, nylon is woven into parachute fabric and ladies' hose. It must be appreciated that nylon can be subjected to any of the manufacturing processes outlined, a familiar example of extrusion being toothbrush bristles.

Compression Moulding Thermosetting Materials

In the case of the thermosetting materials, compression moulding is by far the most common method of manufacture. It is cheap and simple and enjoys a widespread popularity. Unlike the thermoplastics, mouldings in thermosetting materials can be ejected from the mould immediately the "cure" is completed—no cooling of the mould being necessary. One of the drawbacks of this method is the fact that excessive material in the mould forms "flash," which has to be removed by hand.

Transfer Moulding of T.S. Materials

In an endeavour to secure for the thermosetting materials the advantages of quick production made possible for the thermoplastics by the process of injection

moulding, transfer moulding was evolved.

The main difference between transfer and compression moulding lies in the fact that in the latter the raw material is placed directly into the mould cavity, whereas in the former it is placed first into a preheating chamber. In this chamber material is brought to its plastic state and is forced into the mould cavity through a nozzle. Apart from a considerable reduction of the time cycle—which may be as much as 50 per cent.—transfer moulding can be used to advantage when complicated shapes have to be moulded or when flimsy inserts have to be incorporated in the moulding.

Extrusion of T.S. Materials

Extrusion of thermosetting plastics is very similar in principal to the extrusion of thermoplastics. The differences in technique are largely due to the different heat cycles of the materials, whereas in the case of the thermoplastics the extrusion nozzle is at a lower temperature than the heating chamber, the reverse is the case when thermosetting plastics are being extruded. The reason for this is, of course, that additional heat is necessary to complete the "cure."

Laminates

A very important type of thermoplastic materials is laminates. These are manufactured in the form of sheets, rods and tubes, and are made by passing sheets of fabric or paper through a bath of liquid resin, squeezing to control the resin content and drying. The impregnated sheets are then cut to size and built up into a stack. The thickness of the impregnated sheet is in the order of .005 in. and the number of sheets put into the stack depends upon the thickness of the finished sheet. The pack is then placed between the heated platens of a hydraulic press and pressure is applied. Under the action of the heat and pressure the resin flows and finally hardens, bonding the whole into a hard sheet having exceptionally good physical properties.

When rods or tubes are to be produced the impregnated fabric or paper is wound on to mandrels and then pressed between split circular moulds.

Laminates are used extensively by the engineering and electrical industries because of their excellent mechanical and electrical properties.

Coatings and Adhesives

The remarks which were made concerning thermoplastic coatings and adhesives apply equally well to those which are based on the thermosetting plastics. The coatings afford excellent protection against weathering and acids and are used largely to prevent corrosion of steel structures. Plastic coatings can be applied by means of a spray gun and are economical in use.

There are a number of adhesives which are based on the thermosetting resins. These are of two forms—liquid adhesives and dry glue films. The latter are largely used in the manufacture of "densified" wood and consist of sheets of tissue paper which have been impregnated with resin and dried out.

Improved Wood

Mention must be made at this juncture of improved or densified wood. The material possesses many excellent features and is made in a similar way to laminates. Wood veneers inter-spaced with a plastic glue film are subjected to heat and pressure, and the resulting product has exception-

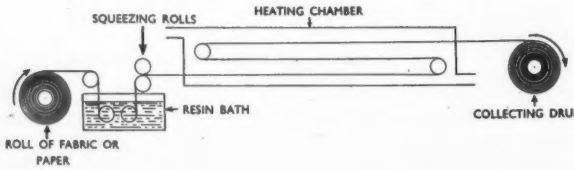


Fig. 4.—Manufacture of laminates.

ally high physical properties. Improved wood can also be moulded to comparatively simple shapes without the use of expensive steel moulds.

The dry glue film is not always employed; in some cases a liquid adhesive is spread over the surface of veneers and sometimes the veneers are impregnated by soaking in a bath of liquid resin.

Physical Properties and Design

Much of the misunderstanding which has arisen on the subject of plastics has been due to the lack of appreciation of the various properties of plastics. Plastics form a new group of materials and must be treated on their own merits if satisfactory results are to be obtained. No engineer would countenance the idea of designing a metal component without having an appreciation of the properties of the metal, yet too often one hears of cases where metals have been replaced by plastics without any difference being made in the overall sections of the component in question. This has led to poor results on test and has done incalculable harm to the reputation of plastics.

One of the most popular misconceptions concerns weight. Although the specific gravity figures of plastics are about half those for the light alloys, in practice it is seldom possible to achieve a reduction in weight of more than 15 per cent. This is because when replacing a metal part by plastics the component has to be redesigned on the strength figures of the plastic. Since these will be appreciably lower than those of the metal, wall thicknesses must be increased, strengthening ribs may have to be introduced, and sometimes metal inserts are found to be necessary.

Another point worthy of discussion is cost. There is a popular idea that all plastics are cheap. Whilst it is true that cheap plastics are obtainable, those having higher physical properties are comparatively expensive. Nor must the cost of moulds be left out of the picture. To obtain a proper view of the economics of a proposed change over to plastic it is necessary first to decide which is the most suitable material, and this can best be done after consultation with plastics manufacturers as to how the article will be made (that is by moulding, forming, extruding, etc.), and the quantities involved. This latter item can often be a deciding factor in selecting the most economical method of production.

Manufacturing tolerances are also the subject of misunderstanding and in many cases proposals are put forward calling for impossibly fine limits. In general, the closest commercial tolerance for moulded plastics is about $\pm$ .0025 in. per inch. If a dimension crosses a mould split, this figure must be increased. Calling for fine tolerances will result only in a high percentage of rejections.

Screw threads can be produced in plastics in various ways—they can be moulded, tapped or be incorporated in metal inserts. When the screwed portion of moulding is likely to be operated repeatedly—especially if the screw is metal—the use of threads directly in the plastic is not satisfactory and metal inserts should be employed. In fact, for all small screw threads metal inserts will usually give the most satisfaction. When moulded threads are used, it is essential that the strength be calculated from physical properties of the plastic in question. When not subjected to heavy loads and when not likely to be in continuous operation, moulded screw threads can be perfectly satisfactory.

A point which should always be borne in mind when designing plastic components is that the general form of the component should be free from undercuts if possible, as these necessitate multi-part moulds, which are expensive. In addition, the moulding cycle is increased due to the extra handling which is required to reassemble the mould after each moulding has been ejected.

The strength of plastics is a subject about which much must be written if it is to be fully understood. Plastics are not so strong as metals and allowances

must be made for this. The behaviour of plastics under alternating stresses and vibration has not yet been fully understood, but from tests which have been carried out the fatigue strength of the thermosetting plastics is about 20 per cent. of light alloys.

The effects of temperature are important, too, for plastics exhibit temperature sensitivity at much lower values than is the case with metals. In the majority of cases the tensile strength of plastics tends to increase at the lower temperatures, but this gain is offset by an increased brittleness.

A further peculiarity of plastics is that they exhibit creep even at atmospheric temperatures. Creep occurs in metals also but only at elevated temperatures, so that in the majority of cases its effects may be neglected. This is not the case with plastics and creep must be taken into consideration in all cases where a plastic component is liable to be subjected to continuous or steady loading. In this connection it has been determined by practical tests that the load which can be supported by plastics (thermosetting) for a period of 30 days is only some 25-30 per cent. of the ultimate tensile strength of the material. This value, that is the steady load which can be supported for a period of 30 days without fracture, is known as the static strength. A typical

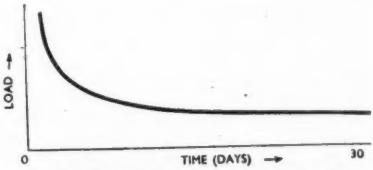


Fig. 5.—Typical static strength curve for thermosetting material.

curve of static load against time is shown in Fig. 5 and will illustrate the point.

The foregoing notes will give some indication of the limitation of plastics, and it is hoped that they may prove to be of some value to those unfamiliar with the subject. The first and most important rule is "design for plastics" and do not attempt to regard plastics as substitutes.

The value of early consultation with the plastics manufacturer cannot be too highly stressed. Given the exact functions of the proposed part and he will be ready and willing to place his experience at the disposal of the customer. He may make alternative suggestions regarding the design, but usually a satisfactory compromise can be reached.

Finally, plastics are not universal "cure-alls," but it must be remembered that they are performing a multitude of useful tasks in many industrial spheres. Used correctly, they have much to offer; incorrect application leads to unsatisfactory results and misunderstanding.

Plastics in Building

The Municipal Journal of July 16 contained some interesting notes on the above subject and reports on the findings of one of the Study Committees of the Post-war Building Directorate of the Ministry of Works. This Committee has been investigating the possibilities of plastics in building construction and its findings appear to follow closely those of Dr. R. J. Schaffer of the Building Research Station at Watford. This body does not consider plastics to be practical in place of wood or steel for the load-bearing parts of building structures. The only application of plastics which the experts recommend for this is resin-bonded plywood, a material which is already being extensively used by the Ministry of Works.

Waterproof glues are another sort of plastic material. Their use is recommended in the construction of timber roof trusses.

While many forms of laminated sheet are useful and decorative, yet cost may restrict their use. Plastic flooring offers considerable possibilities.

While plastics may not yet be practical politics where the main structural members of a building are concerned, they are more adaptable to the construction of window frames, doors and some of the smaller but necessary components.

PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

SYNTHETIC RUBBER PRODUCTION.—In the House of Commons last month, Mr. Shinwell asked the Minister of Production whether he could make a statement on the progress of investigation into the production of synthetic rubber in this country. Mr. Garro-Jones replied that certain suggestions for production in this country have been communicated to the Minister of Production by a British firm who have been asked for further information. Mr. Shinwell then asked if it were not true to say that the British firm have made a firm offer to the Mihister that they are ready to install plant and that all that is required is the consent of the Minister to enable production of synthetic rubber in this country. "Why," said Mr. Shinwell, "should we not produce synthetic rubber instead of allowing an important commodity of this kind to be produced elsewhere?"

Mr. Garro-Jones replied that while it is true that the firm in question are confident that they can produce synthetic rubber, the Minister of Production must satisfy himself that their confidence was well founded.

BRITISH STANDARDS INSTITUTION.—The annual general meeting of the British Standards Institution was held on July 20, following a luncheon at which the Rt. Hon. Mr. Hugh Dalton, M.P., President of the Board of Trade, was the principal guest. The chairman, Sir Percy Ashley, K.B.E., C.B., said that 230 new and revised British Standards had been issued during the past year. The total number of British Standards now in use numbered 1,500, all of which could be consulted at the Library of the Institution, where copies of Overseas Standards are also available.

In the course of his address the chairman said that the constitution of the Institution provided flexibility and adaptability which had enabled it to make a powerful contribution to national efficiency, a contribution all the more effective because in the main it had been devoid of any element of compulsion, but had been based on the principle of consent and voluntary co-operation with Government encouragement and assistance but without Government control. He added: "I believe that those industries which have been long and closely associated with the development of the Institution recognize fully the advantage of having a single, independent, national standards organization. But those others which are only now beginning to consider the opportuneness of the time for a standardization programme covering types and sizes, trade terms, definitions, and performance standards, may feel that the preparation and promulgation of standards is a matter of domestic concern and should therefore be carried out by their individual trade associations. There has also been some tendency for Government Departments to do standardization work in their own ways and on their own lines. I believe that both these courses are wrong in principle, and that the best results for any industry, and certainly for the industry of the nation as a whole, will be obtained only if all this work is carried on within a national organization such as the British Standards Institution which can co-ordinate and guide all such action to a common end."

PRODUCTION AUTHORITIES GUIDE.—The Ministry of Production has just produced a guide which shows at a glance which is the authority responsible for the production of manufactured products that are not obviously the concern of a single Government Department. Neither industry nor departments have any difficulty in knowing, for instance, that tanks are the responsibility of the Ministry of Supply and aero-engines of the Ministry of Aircraft Production. But between such well-defined classes of munitions is a vast number of products which, because they are used in a great variety of finished articles or for many different purposes, are common to more than one department.

These common products are so varied that they include, for instance, agricultural machinery, anti-gas equipment, benzole, bicycles, ball bearings, bolts, nuts and screws, cement, clothing and footwear (not only for civilians but also for the Armed Forces), locomotives, pencils, tobacco and tyres.

This guide, called "The Production

Authorities Guide," contains a list of 194 products, the production authorities responsible for each, and other details such as whether control is exercised by Order or whether there is an Advisory Trade Panel. It has been printed for the Ministry of Production by the Stationery Office, price 4d.

GAUGE AND TOOL MAKERS ASSOCIATION.—In order to allow more time for the nomination and election of members of Council for the new Session, the annual general meeting of the Gauge and Tool Makers Association, which was to have been held on July 7, will now take place on Wednesday, September 1, 1943. Proceedings will commence at 2.30 p.m. and the meeting will be held at the offices of the Association, 2-5, Old Bond Street, London, W.1.

Copies of the Association's booklet, which includes details of the aims and objects, a schedule of the annual subscriptions, and a list of the existing members, are available on application to the secretary.

PRODUCTION PLANNING. — The Ministry of Labour and National Service, in conjunction with the Board of Education and the Scottish Education Department, is organizing courses of lectures on Production Planning at various Technical Colleges throughout the country. The lectures will cover the following subjects:—Workshop Organization and Lay-out of Plant. The Operation Lay-out. Materials. Control of Quality. Motion and Time Study. Final Operation Lay-out. Workshop Economy.

The courses will normally be of 20 hours' duration and will usually be given in evening meetings of two hours each. No fees will be charged for the courses.

The courses are intended for men and women engaged on planning work in firms or with experience of such work and others with comparable experience who are capable of benefiting from the instruction given.

Names and addresses of persons put forward by their employers or applying for the course on their own account should be sent to the local Employment Exchange with a reference to the scheme and with full details of technical experience and present employment.

THOMAS DE LA RUE AND CO.—The net profit, before taxation, of Thomas De La Rue and Co. for the 15 months ended March 27, which was estimated in the preliminary statement at not less than £300,000, turns out from the full accounts to be £342,914 (the nominal amount of the issued capital is £347,000). The reservation for tax is £165,000, which leaves a net figure of £177,914, or £142,331 per annum; for the preceding accounting period of 21 months the net figure was £62,214, or £35,551 per annum. The surplus over the 35 per cent. dividend is used in placing a further £50,000 to general reserve (making it £250,000) and in increasing the forward balance from £61,694 to £68,158. In their report, the chairman and managing director state that the company is not mainly dependent for its success on its plastics business—all sections of the undertaking contributed to the satisfactory results now submitted. The chairman stated that the new subsidiary, De La Rue Plastics, is the largest plastic moulding concern and that a steady expansion is expected.

NEW COMPANIES

Scottish Plastics has been registered to acquire the business of the Scottish branch of De La Rue Plastics. Capital £250,000 in £1 shares.

PERSONAL

Dr. W. E. de B. Diamond, M.A., A.I.C., who was unanimously selected by the Selection Committee of the British Plastics Federation to be General Manager, has had a wide experience to fit him for his new post. He is 44, graduated at Clare College, Cambridge, and is also a Fellow of the Chartered Institute of Secretaries.

After holding Government and other posts abroad, Dr. Diamond was, in 1937, appointed to his present position of Assistant Secretary to the Institution of Gas Engineers, and owing to special conditions arising from the war he has during the past three years been responsible for the major part of the business and administration of the Institution.

Mr. Charles H. Glassey has now fully recovered from the illness which obliged him some months ago to resign his office of Deputy Controller of Plastics. He has rejoined the Board of British Industrial Plastics, Ltd., and has recently been appointed Director of Development of that company, in which capacity he will co-ordinate the work of technical development throughout the B.I.P. group of companies. Mr. Glassey will operate from the head office of B.I.P. at 1, Argyll Street, London, W.1.

New Tensile Test Piece for Plastics

Presenting Results of Research by Frischmuth from "Schweizer Archiv," 1943/8/24. Problems Encountered are Critically Discussed

A RECENT report by B. Frischmuth described comparative tests with a new form of test piece for plastics; this form was suggested at the Plastic Conference in Zürich, August, 1941.

Fig. 1 shows the shape and dimensions of the test piece, which is characterized by a cylindrical recess with a ball-shaped end. The dotted line corresponds to the form proposed by Grimm* as giving the least possible variation in cross-sectional area. The practical form has been simplified for reasons of design and moulding technique.

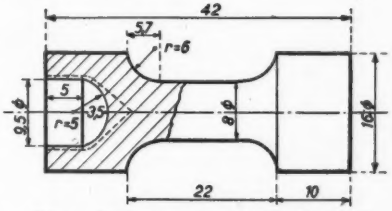


Fig. 1.—New tensile test piece for plastic mouldings, according to Frischmuth. Attention has been directed chiefly to the attainment of structural homogeneity and hence to the assuring of representative properties in the gauge length of the test piece.

The test pieces examined were made from the same mould by five different moulding concerns. Table 1 shows the different materials, consecutively numbered but arranged in groups; the

*See also "Plastics," 1943/7/251.

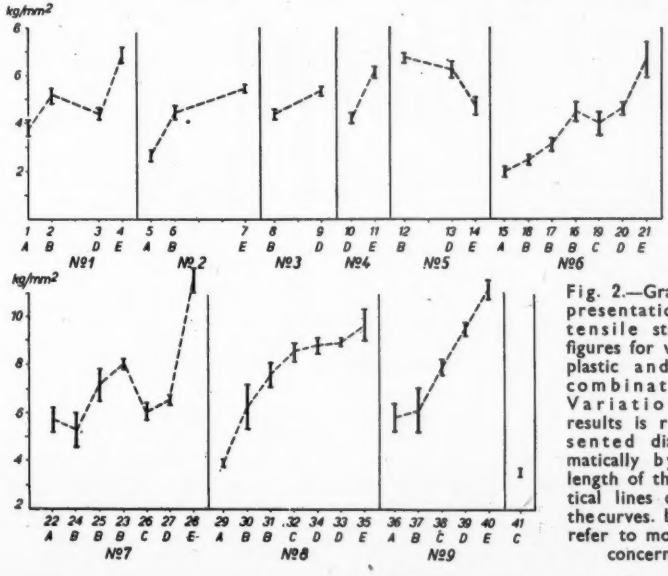


Fig. 2.—Graphical presentation of tensile strength figures for various plastic and filler combinations. Variation in results is represented diagrammatically by the length of the vertical lines cutting the curves. Letters refer to moulding concerns.

moulders are designated by letters A to B.

As for each material 6-12 samples were always available, tensile strength is given as the arithmetical means, error being given on an r.m.s. basis. In spite of the fact that these results do not represent actual errors of observation, the calculated values can be considered as indication of the variations encountered. Exact calculation by statistical methods was not possible owing to the small number of measurements.

The values obtained for given moulding materials, worked up by different concerns, vary considerably. In Fig. 2, tensile strengths are arranged in alpha-

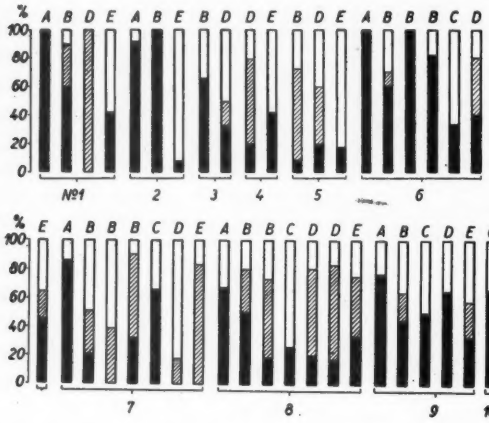


Fig. 4 (left).—Distribution of fracture position in test pieces broken in tension; in gauge length, 47.5 per cent.; at neck of gauge length, 19.2 per cent.; in transition zone, 33.3 per cent.

betical order of the moulders. The length of the full vertical line corresponds to the observed variation. With the exception of one material (phenolic resin with textile fibre), strength in all cases increases in a very arbitrary manner. Pre-pressing and pre-heating promote increase in mechanical strength. Comparison tests were made in the case of urea resins (Materials No. 6, 7 and 8).

As moulding conditions have a decisive influence on the properties of the test bar, factors such as pressure, temperature, time, etc., were compared. In spite of the fact that these data were not recorded and measured under equal conditions, a characteristic relationship between tensile strength, moulding pressure and moulding time was found. Fig. 3 shows an increase in strength occurs with increased pressure (in the cases 15A and 19C, only the total piston pressure was known).

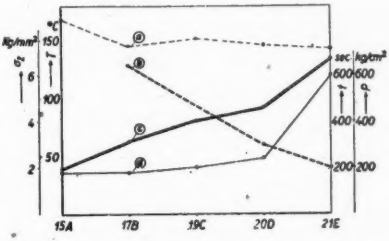
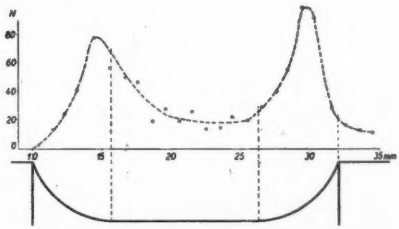
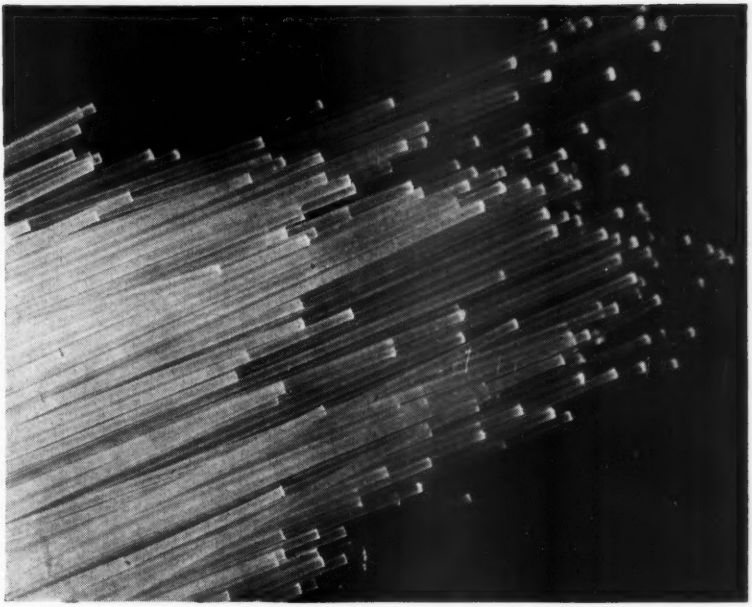


Fig. 3 (above). — Variation of tensile strength with moulding condition for a urea-resin test piece with asbestos filler: a, moulding temperature; b, moulding pressure; c, tensile strength; d, moulding time.

Fig. 5 (below). — Frequency curve of broken test bar lengths. Abscissa in mm.; ordinate-number (n) of broken bars.



Influence of temperature cannot be inferred with safety, as the data given by the moulders do not refer to the same measuring point. Owing to the thermal sensitivity of urea resins, a reduction in strength at higher temperature can be expected, as may be deduced from the



NYLON

The name nylon has been given to a number of products of the type known to chemists as superpolyamides. These products are thermo-plastics of high melting point, and can be made into tough filaments or threads.

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diagram. Comparisons with other moulding materials indicate that, for urea resins, the influence of pressure and time is greater than that of temperature.

Measurement of elongation could not be carried out by the usual means owing to the short length of the test piece. Extension in plastics of the type being investigated is usually small and, therefore, can be neglected.

Phenolics with wood flour filler, which fracture smoothly, can be fitted together again, so that the break can hardly be seen with the naked eye. In the original article different fracture types in the materials tested are discussed at length, but the arguments advanced have no bearing on the suitability of the test bar. Valuable information in this respect, however, may be obtained from the position of the fracture in relation to the total length of the sample.

Fig. 4 shows for each material the relative frequency of the fracture in the gauge length, just outside gauge length, and in the radiused fillet. Comparing all samples, only 47.5 per cent. broke in the

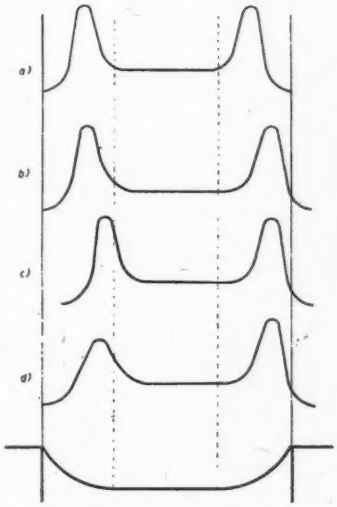


Fig. 6.—Analysis of distribution curve (see Fig. 5) in terms of the influence of elongation prior to fracture and of errors in measurement.

Table 1.—Investigated Moulding Materials.

No.	Moulding material		No. of samples	Tensile strength kg./sq. mm.	Variation	No.	Moulding material		No. of samples	Tensile strength kg./sq. mm.	Variation
1A	No. 1	Phenol resin with wood flour	12	3.84	0.70	22A	No. 7	Urea resin with pure cellulose (Cibanoid V)	13	5.73	1.07
2B[1]			10	5.17	0.57	23B[1]			10	8.05	0.31
3D			5	4.37	0.40	24B[3]			8	5.28	1.42
4E			12	6.91	0.77	25B[4]			10	7.24	1.34
						26C			12	6.08	0.71
5A	No. 2	Phenol resin with asbestos fibre	12	2.58	0.33	27D			6	6.64	0.38
6B[1]			10	4.43	0.46	28E			12	11.58	1.00
7E			12	5.43	0.29						
						29A	No. 8	Urea resin with wood flour (Cibanoid BH)	12	3.89	0.30
8B[1]	No. 3	Phenol resin with asbestos powder	12	4.34	0.40	30B[1]			10	6.38	2.00
9D			6	5.29	0.35	31B[2]			11	7.60	0.99
						32C			12	8.50	0.72
		Phenol resin				33D[5]			5	8.94	0.27
10D	No. 4	with textile chips	5	4.20	0.40	34D			6	8.77	0.58
11E			12	6.16	0.49	35E			12	9.66	1.37
12B[1]	No. 5	Phenol resin with textile fibre	11	6.70	0.24	36A	No. 9	Melamine resin with pure cellulose (Melopas)	13	5.78	1.33
13D			5	6.22	0.67	37B[1]			11	6.16	1.82
14E			12	4.69	0.77	38C			12	7.92	0.60
						39D			6	9.51	0.58
15A	No. 6	Urea resin with asbestos fibre	12	1.96	0.39	40E			12	11.22	0.76
16B[1]			10	4.51	0.82						
17B[2]			6	3.12	0.56						
18B			11	2.46	0.30						
19C			12	4.04	0.81	41C	No. 10	Mixed melamine resin with wood flour	12	3.56	0.35
20D			5	4.58	0.45						
21E			11	6.65	1.42						

[1] Mixture pre-heated for 20 mins. to 40 deg. C. [2] Not pre-heated. [3] Mixture dried over $CaCl_2$.
[4] Pre-pressed. [5] Low moulding temperature.

gauge length; 19.2 per cent. are boundary cases and the remaining 33.3 per cent. represent fractures in the fillet portion, and these must be considered as unfavourable cases, as the breaking did not occur in the smallest cross-section. Calculated tensile strength was always referred to the smallest cross-sectional area.

The problem was further analysed by statistical methods. Fig. 5 shows the relative frequency of the length of fracture ends from the head portion plotted against the length of the sample. The basic length for each group was 1 mm., the total number of measured lengths was 816, corresponding to 408 samples. The two very pronounced maxima reveal, definitely, a weakness of the radiused portion.

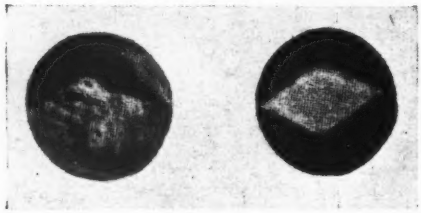


Fig. 7 (extreme left).—Nylon-type plastic with cellulose filler (Cibanoid V). Surface of fracture (x 3). Fig. 8 (adjacent left).—Nylon-type plastic with cellulose filler, showing fracture after grinding flat. Interior of test piece has not been hardened homogeneously (x 3).

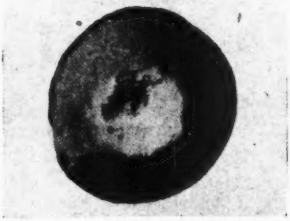
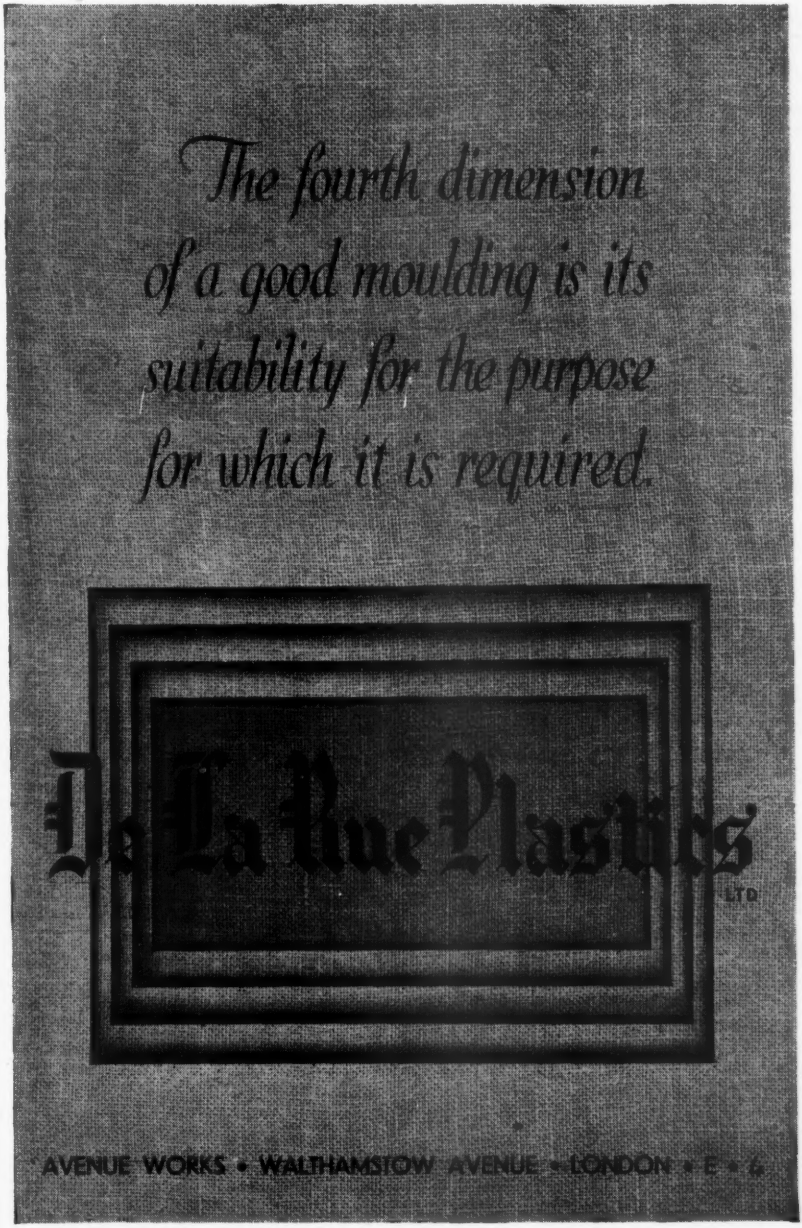


Fig. 10 (right).—Cross-section of fractured test piece end shown in Fig. 9. The homogeneous zone responsible for the anomalous fracture is clearly seen here.

Fig. 9 (above).—Nylon-type plastic with cellulose filler showing form of fracture at the junction of gauge length and gripping end of the specimen (x 2.75).

By a still more detailed analysis further conclusions can be drawn. The frequency of fracture should, according to statistical principles, be symmetrically distributed about the middle of the bar, i.e., with reference to the group 21 mm. This would be the case only if all fractures were perpendicular to the axis of the bar and where elongations were so small as not to enter seriously into the measurement; if, however, elongation be present, the frequency curve must become deformed by reason of the measuring technique. The increase is, of course, proportional to the length of the fractured piece. In Fig. 6a is shown the ideal distribution curve; this is converted in Fig. 6b, assuming a distinct elongation per unit of length.

Further deformation is due to sliding fractures, and in this case, maximum measurable length was always recorded. With an inclined position of the fracture, the total length of the two fractured halves will be greater than the original length of the bar. These conditions are considered in Fig. 6c, which is shifted by errors of measurement to the right-hand side. If curves b and c are added and the ordinates halved, curve 6d results; this conforms well to the form of the experimental frequency curve.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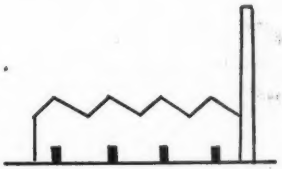

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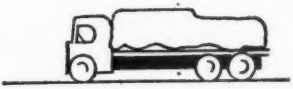

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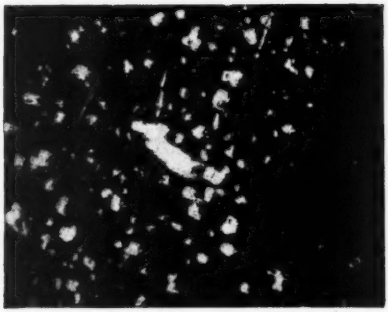

Fig. 11.—Phenolic resin with wood-flour filler. Ground micro-section of surface at fracture (x 40).

This analysis of the asymmetrical behaviour of the test pieces is necessary in order to find the exact position of the weak portions. Two conclusions are drawn: (1) The weak point lies definitely in the radiused fillet, not in the transition to the shank and not in the headed portion. A weakening of the bar by notch action cannot be assumed. (2) Some of the samples investigated must have a measurable elongation. A device for measuring the elongation of small test bars would be valuable.

In conformity with former observations by Grimm it can be shown that in spite of the improved test bar with recesses in the head portion, the material was not fully cured. This could be demonstrated in the case of the urea resins, where the porous zone is rendered visible by its lighter colour (Fig. 7). When the section is ground and polished the zone becomes still more visible (Fig. 8), and the same pointed ends lead to the seam of the mould. Fig. 9 shows a bar of the same material with fracture near the head; the bar was sawn longitudinally (Fig. 10) and showed distinct zoning. From the head portion a small zone is fully hardened, then a porous zone follows. Owing to this, fracture will occur where the cross-sectional area of the fully hardened material is a minimum, and not at the geometrically smallest cross-section.

Shape and position of the porous zone may vary according to moulding conditions. In particular, temperature distribution during moulding will have a great influence. If the bar can be uniformly hardened, fractures in the radius could be avoided; the bar would then break in the shank and a criterion for the strength of the moulded part could be obtained.

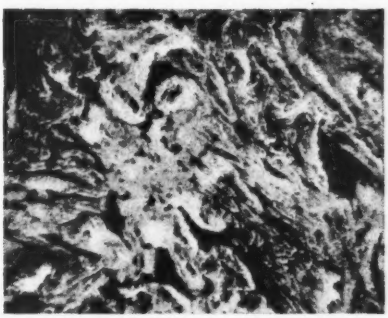

Fig. 13.—Phenolic resin with textile-chip filler, showing micro-structure in vicinity of fracture (x 40).

Fig. 12.—Phenolic resin with textile-fibre filler showing micro-structure of surface in vicinity of fracture (x 40).

By grinding and polishing the fractures in other materials zoning due to insufficient hardening was investigated. Fig. 11 shows the surface of a phenolic resin with wood-flour filler. The light spots are larger resin drops accumulated at given points. Filler and resin were not sufficiently mixed, and temperature distribu-

tion was obviously not uniform. The portions with high resin content naturally reduce the total strength and give rise, as well, to insufficient hardening. In the case of phenolic resins with textile fibre (Fig. 12) and textile chips (Fig. 13), irregularities in the cross-section cannot be well seen, as during the grinding process projecting fibres are smeared and pressed into the surface.

The obvious conclusion is that uniform hardening should be sought by alterations in the form of the head. Fig. 14 shows the variations in cross-sectional area for the test bar investigated. It gives also the course of the cross-section plotted against the length of the bar. The zones of insufficient hardening are shown by hatching. They are obviously caused by the increased cross-sectional area and the impossibility of correct heating during moulding. The bottom sketch gives the cross-section according to Grimm's test piece. The danger zone is considerably smaller as the pointed recess allows for better temperature distribution.

Before accepting the new shape proposed, further comparison tests seem to be indispensable; a change in the mould should also be considered. In the present arrangement the bar is pressed in a vertical position, i.e., in the direction of the tensile stress, and, owing to this, its upper and lower ends will be differently treated. A moulding in horizontal direction would give a better guarantee of uniformly distributed pressure and satisfactory hardening.

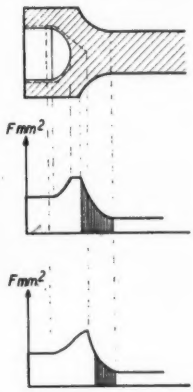

Fig. 14 (upper sketch). — Sketches at top and in centre show section proportions in test piece according to Frischmuth. Sketch at bottom shows section proportions in test piece according to Grimm.

Laminated Plastics in Aircraft Construction

At a recent meeting of the American Society of Mechanical Engineers, W. I. Beach, chief plastics engineer of the North American Aviation Corporation of Inglewood, California, described some of the plastic materials and methods of their fabrication now being employed by his company to replace aluminium sheet in aircraft construction.

The phenol-formaldehyde resin laminated material is very suitable for many stressed and semi-stressed structures, for by suitable preparation and manipulation laminated sheets can be shaped into simple or fairly complex curved patterns.

In general the synthetic resins employed are specially produced materials of a controlled and comparatively low molecule weight, thereby being far from completely polymerized and capable of being shaped in the laminated form to a much greater extent than those resin-laminated sheets normally employed for flat sheet manufacture. Mr. Beach drew attention to the analogous characteristics of aluminium sheet and laminated sheet in allowing " crystalline " slipping and ordered movement in different directions.

Treatment of Porous Castings

The problem of treating porous castings with plastic materials has received widespread publicity. The July issue of " Plastics " dealt with one aspect—the application of the thermosetting type of material which not only sealed the pores but would also stand up to fairly high temperatures. Where these high temperatures are never encountered, for example, in refrigeration plant castings where gas tightness is essential, the use of polyvinyl compounds and polystyrene in solution has been suggested. These plastics are not, however, resistant to methyl chloride.

Co-operation— between User and Moulder

Continuing his notes in the July issue, the author deals with some of the especial difficulties confronting the manufacturer of Precision Mouldings, and the various ways in which closer understanding between the User and Moulder may be established to ensure fullest and most satisfactory interpretation of User's requirements

By
W. M. HALLIDAY

Designing and Constructing the Mould

Assuming the client's acceptance of the quotation based upon the foregoing information, the moulder will then be free to concentrate upon the task of mould design and manufacture proper. It will be recalled that for quoting purposes the broad principle and outline of mould construction will already have been decided. His task now will be to fill in the many details furnishing all the requisite information needed in his own works for the economical manufacture of the tools. In this respect it is obvious that very important decisions or activities have to be undertaken and a study of best practice will be useful.

Use of Detailed Drawing

Some manufacturers omit detailed drawings of each unit component of a mould, choosing only to supply their tool-making departments with assembled drawings showing the entire mould construction and mode of operation. This course may be quite sufficient and actually time saving in respect of moulds of very simple design, when the machinist can derive a clear picture of the tool by reference only to the assembly drawing. But in the case of moulds of complex design, intricate method of working, or large number of parts, something more is usually required even with highly skilled toolmakers.

Therefore it is advisable to arrange for supplying detailed drawings showing the requirements of each individual mould part. This course is strongly to be recommended because it will lead to a reduction in errors, misconceptions, and spoiled workpieces.

In the case of very complex mould constructions the adequate portraying of the assembled arrangements may be difficult even by means of the detail and assembly drawings. One very important method employed by the author for facilitating clearer indication is that employing colour distinguishing means. Thus on the assembly and sectionized drawings the various portions of mould such as runners, sprue, gates, ejectors, cavities, etc., are depicted by different colours washed over the usual cross hatching denoting different parts or materials.

By this simple and inexpensive means the mould engineer will be enabled to gather a much clearer idea in a shorter space of time and, as a result, will gain greater understanding and confidence which of itself will assist towards obviating errors or faulty machining.

On this matter of mould drawing and presentation for the use of machining departments much might be usefully written, but at this stage space precludes anything but the briefest mention of one other important consideration.

This relates to the method or system of dimensioning mould drawings. Wherever possible all dimensions, and especially those critical for precision features, should be related to a datum line, this latter being positioned so as to

coincide with either two exterior sides of the mould blocks to be used, or to a given imaginary line beyond. If this is done a great simplification will result when having to lay out, mark off, or locate blocks on the machine table for machining of the cavities.

All such dimensions should also be so arranged as to avoid any computations on the part of the machinist to ascertain essential figures. Here again this will eliminate another very fruitful source of error.

It is emphasized that modern machining methods either by die-sinking machine of the Keller or Deckel type, or precision milling machine, or jig-boring machine all three methods being largely employed nowadays, each specially lends itself to location of components for machining by datum-line form of dimensioning, and if utilized will result in very appreciable savings.

Of course, where it is possible the user's sample moulding should be passed along to the mould engineer in order that he can gain a yet clearer picture of the article to be produced. Such a sample, or a drawing of same, or even a photograph, can in many instances render great assistance by affording an instant clarification of a toolmaker's difficulty of visualizing the configuration or construction of a complex moulding.

Gauging and Inspection for Duplicity of Parts

One remaining difficulty only may be dealt with in this present article, though this by no means exhausts all the numerous points upon which it is desirable the moulder shall devote close study.

This problem then concerns the gauging and inspecting of finished article so as to obtain the continued acceptance of client throughout production of complete order.

In the case of a multiple cavity mould, when having been tested samples should be submitted to client in usual way, but a special point to watch is that three or four samples at least from each mould cavity be sent, instead of one or two from a few of the cavities.

Such samples should, of course, only be sent to purchaser after the moulder has given them most careful checking to ensure full agreement with specification requirements.

A request should also be made for the user to return at least one sample from each cavity approved by him, these being retained with the user's O.K. by the moulder as final word in the case of disagreement. It often happens that the user will approve the presence of slight departures from specified features which have unwittingly arisen. In such cases the moulder should return moulding drawing and specification to user to secure his alteration of same in line with approved sample.

If this is always done it will assist in eliminating much argument and heat which may otherwise arise as production proceeds, and which, as the writer knows from experience, may be exceedingly unpleasant for both client and moulder.

It is the moulding manufacturer's responsibility to ensure that once full approval has been obtained for the sample moulding all ensuing bulk productions shall be faithful reproductions thereof, avoiding any departures from sample features or specification requirements. In the case of the precision moulding this will obviously entail a very considerable degree of inspection and checking. It may not be necessary to subject every moulding to such close inspection, or to submit all dimensions to exact gauging.

Again inspection for such matters as the chemical, electrical, or mechanical, or physical properties, such as, say, hardness, durability, ageing, tensile or impact strengths, shrinkage, breakdown voltages, or volume-change resistances, clarity, colour range and intensity, may be conducted very intermittently as it is possible to furnish very precise determination and control of same.

The necessary inspection activities to be carried out to ensure dimensional accuracy and exact duplication of shape and sizes should be designed as near fool-

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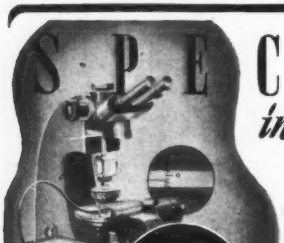

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proof as possible, and care taken to coincide with either two exterior sides to prevent subsequent machining or finishing operations from distorting or damaging mouldings so as to render gauging impossible or ineffective.

In conclusion, then, mouldings of closely controlled precision standards of inter-changeability, and accuracy are certainly easily practicable provided there has been formed a sufficiently close degree of understanding between the would-be user and moulder throughout all stages of negotiations for supply of mouldings, but especially through early stages where it is more readily possible for misconceptions, mistakes, and trouble being caused.

Summarizing the previously mentioned suggestions it may be urged that the user should receive at the initial stages of the mouldings development a clear appreciation of the limitations imposed by process together with fullest information of the control of sizes and other desired features possible to the moulder.

On his part he should take every possible step to collate all his requirements in the finished moulding, so transmitting them to the manufacturer as to avoid inadequate or faulty interpretations arising at the other end.

The moulder, too, should carefully consider the mouldability or practicability of article in the light of moulding experience and should faithfully reciprocate by imparting any constructive criticisms or useful suggestions which imply important departures from client's needs.

Upon acceptance of order for supply of such mouldings then mutually agreed upon, it should be his constant endeavour to maintain uniform, accurate reproduction to agreed standards as previously intimated.

Markers and Binders for Cables

THE maintenance and servicing of electrical equipment is often accompanied by unnecessarily difficult conditions, most of which are easily avoidable by the taking of a few simple precautions.

The tracing and repairing of cable faults is a good example of this.

Modern methods have provided identification labels, known as "markers," which eliminate all the labour finding the broken cable and save the workman's time of testing each section of a complicated mass of unmarked cables.

The form which these markers may take may be one of several, but for practical purposes, a most satisfactory marker is provided by the "Lassolastic Identification Tape," which is made by the Herts Pharmaceuticals, Ltd., the manufacturing chemists of Welwyn Garden City.

The "Lassolastic Identification Tape," each marked with an appropriate designation, has been developed from a sealing tape which was produced to meet an urgent demand for a form of sealing which could be readily applied to all kinds of containers in order to render them airtight and insect proof. From this sealing tape was evolved this now well-known identification tape by preparing it on a base of rubber hydrochloride film—"Pliofilm," the nature of which is such that an extremely thin (.002 in. thick) and pliable film can be produced which is completely waterproof and highly resistant to the effects of oil and heat.

The application of this system of marking is limitless. It is in use by aircraft constructors, armoured vehicle manufacturers, and the makers of machine tools, electrical control and appliances, also by shipbuilders and allied engineering trades.

Other products of the Herts Pharmaceuticals, Ltd., are "Lassovic" and "Lassoband." The former is a tape with a polyvinyl chloride base with remarkable properties in that it is immune from damage from a very wide range of chemicals. Electrically this type of tape is good and may be used with little restriction other than is common to "Pliofilm." The latter, "Lassoband," is a self adhesive identification tape which has been evolved by using a cellulosed covered cloth, which renders it more rigid and therefore suitable in those special circumstances where limits are tight, and where the register of the designation must be extremely accurate.

Resinoids and Other Plastics as Film Formers

By B. J. BRAJNIKOFF,
Consulting Electrical Engineer

XIX (Contd.).—Electrolytic Aspects of High Polymeric Systems

Chemical Interaction Between the Components of the Solution

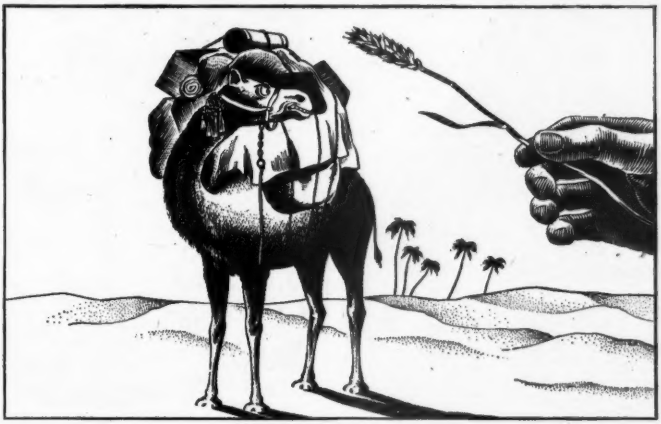
The chemical reaction between the constituent elements of a solution (solvation, formation of definite chemical combinations) is usually regarded as a source of emergence of various anomalies in the behaviour of the solutions of electrolytes (the fall of the molecular electroconductivity with the increase of dilution, the negative temperature coefficient of the electroconductivity). Walden[291] already in 1903 had isolated a special group of the "anomalous electrolytes," for which, in contradistinction to the "normal" electrolytes, conforming to the postulates of the theory, the governing factor is the interaction between the component parts of the solution.

There has been carried out a number of attempts to evolve a special theory of the "anomalous" electroconductivity, the most complete of these efforts being the work of Sachanoff.[292] This division of electrolytes into the "normal" and the "anomalous" could hardly gain a general acceptance, since in this case the chemical factors have been considered only from the angle of building hypothesis of the "anomalous" dissociation, and, falling far short of explaining all the phenomena, merely reflected the inconsistency of the whole theory; the disagreement with such a division is the more legitimate if we remember that even the "normal" electrolytes in the state of high concentrations exhibit the same peculiarities, which are ascribed to the "anomalous" electrolytes as their characteristic features. To build a generally valid theory of the electrolytes it is imperative to include a systematic study of the anomalous electrolytes with the aim of deeper penetration into the nature of the so-called "anomalies."

Hlasko,[293] who conducted a large number of investigations on the electroconductivity of non-aqueous solutions, has independently arrived at the conclusion similar to the Usanovitch school that the requisite condition of the conductivity is the formation of chemical combination between the components of the solution. The experimental results obtained by this author, like those of Plotnikoff, Fredenhagen and other workers, definitely militate against the recognition of the dielectric coefficient of the solvent of the role of a factor determining the "dissociative power" of this solvent.

Incidentally, even the chief protagonist of the latter concept, Walden,[294] had to revise this point of view and expressed the opinion that solvents with approximately equal dielectric coefficients [for example, CH_3CN and CH_3OH or $(CH_3)_2CO$ and C_2H_5OH] depending on their chemical properties, exert a different influence on the dissolved electrolytes. In his work relating to this problem, Walden[295] has abandoned his former views on the dielectric coefficient. The results derived by Usanovitch and co-workers from the experiments on the electroconductivity of H_2SO_4 in $(CH_3)_2SO_4$ and CCl_3COOH, conclusively decided the question concerning the role of the dielectric coefficient.

As a consequence of the close study of the systems: H_2SO_4—$(CH_3)_2SO_4$ [dimethylsulphate, $\epsilon = 54.5$] and H_2SO_4—CCl_3COOH [trichloracetic acid,



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$\epsilon = 4.55$], in which the component parts form no chemical combination, there was found a dependence of the electroconductivity upon the concentration. It has been established that the influence of the second component is determined only by its internal friction; the introduction of correction for the coefficient of internal friction (i.e., the viscosity of a liquid) leads to the fact that the electroconductivity measurements of the two systems may be represented by one and the same performance curve. The fact of the coincidence of the superimposed curves of the electroconductivity of sulphuric acid in the two solvents, which radically differ from one another with respect to the value of the dielectric coefficient, as well as the data yielded from the examination of a series of other systems, refute the Nernst-Thomson rule.

The fact that the curve of the specific electroconductivity of the systems: H_2SO_4—$(CH_3)_2SO_4$ and H_2SO_4—CCl_3COOH, the component parts of which do not enter into the chemical reaction, and thus belong to a new type, leads to the conclusion that the usual course of the performance curves of the specific electroconductivity testifies to the formation of a chemical union between the components.

By special examples, and also in a general manner, Usanovitch and his colleagues have demonstrated that all curves hitherto derived from the molecular electroconductivity are of the "anomalous" nature, i.e., the notion of the "anomalous" electroconductivity has no meaning. Therefore, the theory of the electrolytes should be developed by taking into due account the formation of definite chemical compounds between the component parts of solution.

As to the latest theories of the electrolytes, it should be remarked that, with all the radical distinction of their model concepts and the mathematical tools, they repeat the mistake of the classical theory, considering the composition of an electrolyte as known in advance, whereas, actually, in the solutions, in Usanovitch's opinion, there exist not those ions, which form the basis of the calculations, and only in some specially well-defined cases (of low concentrations) can the theory coincide with the experiment. The explanation of such a coincidence Usanovitch sees in the circumstance that, according to the Ostwald's postulate, the ionic concentration is determined by the law of mass action; if a true electrolyte is the combination of that constituent, which was previously regarded as the electrolyte, with the second component—the solvent—then the concentration of the true electrolyte should be expressible by the same law of mass action, in consequence of which the real picture should, in the formal sense, be analogous to that which is supplied by the classical theory. In this event the similarity should be observable precisely in the domain of small concentrations of the "electrolyte" of the classical theory, because, in conformity with the law of mass action, it is exactly here on account of a great acting mass of the second component ("the solvent"), the concentration of a combination, that is being formed, asymptotically tends towards the concentration of the "electrolyte" in terms of the classical theory.

The formation of a definite chemical combination between the component parts of the solution, which thus performs the functions of the electrolyte in this solution, represents, on the basis of the experimental results of the Usanovitch school, the most typical and frequent case. Usanovitch, however, does not regard this typical case as solely possible; contrariwise, he has succeeded in examining two systems already referred to above: $H_2SO_4 - (CH_3)_2SO_4$ and H_2SO_4—CCl_3COOH, in which a chemical combination does not occur, and whose electroconductivity depends entirely upon one of the components. Nevertheless, in the latter systems Usanovitch and his coworkers also did not find the "normal" electroconductivity; the curves of the molecular electroconductivity obtained by the above authors are anomalous throughout.

Thus the experience of the Usanovitch school shows that these investigators have met neither in their own experiments, nor among published records, even a single system whose electroconductivity would be conditioned by the dissociation of one of the constituents (electrolyte), and would be free from complications caused either by the interaction between the component parts, or by the decomposition of the associated molecules into the simple ones.

The Stability of Lyophobe Systems

Turning now to the modern conceptions on the stability of the lyophobe colloidal systems, as typified by the solutions of high polymeric compounds, it may be stated that they are based on the idea of the governing role of the electrical charges on the surface of the colloidal particles, giving rise to the appreciable forces of repulsion between the particles, which are thus prevented from associating into larger aggregates.

With regard to the origin of these charges, there exist in the colloidal chemistry various notions, the most important of which may be considered (i) the adsorption and (ii) the dissociation points of view. According to the first, the charges on the particles are emerging together with the ions adsorbed from the surrounding solution, and according to the second, the charges are evoked as a result of the dissociation of surface molecules forming part of the colloidal particle or, more precisely, of the micelle, meaning, by the latter term, the whole complex of the substances which characterize the composition of the dispersed phase of the colloidal system.

As has been indicated in one of the researches of Karguin[296] at the Moscow Physico-Chemical Institute, it is hardly possible to draw a basic distinction between these two standpoints, if to take into account that in most cases of adsorption (the activated chemical adsorption, etc.), there take part the forces, whose nature and order of magnitude are indistinguishable from the chemical forces. Therefore, the adsorbed ion differs very little from the ion that remains in the micelle in consequence of the dissociation of the ionogene complex. Thus, the various points of view lead, practically, to one and the same picture of the ionic distribution in the colloidal system: on the surface of the colloidal particles there are present ions, which condition the charge of the particle as a whole and thereby the total (thermodynamical) difference of the potentials between the particle and the surrounding liquid, in which are diffused in a greater or lesser degree the ions of the opposite sign, or compensating ions, that ensure the neutrality of the system.

According to the viewpoint expounded by Pauli and Valko,[297] the surface of the colloidal particle contains various molecular complexes formed by the substance of the particle with electrolytes, which condition both the formation and the stability of sol. These complexes represent the ionogene groups decomposable during the dissociation into the ions, which remain on the surface of the particle and communicate to it the charge, and into the ions of the opposite sign, which are distributed through the diffusion in the adjacent fluid medium, thus constituting the outer boundary of the double electrical layer. In such an event it is considered that the complex ions determining the particle charge are inseparably bound up with its surface, and their concentration in solution is, practically, equal to zero, whereas all the ions of the opposite sign, which are found in the colloidal system, are the compensating ions.[297]

The idea of the ionogene group, as a chemical complex, even prior to Pauli, has been proposed by Duclaux.[298] Pauli, with the aid of the ingenious physico-chemical method developed by him, has succeeded in examining the chemical structure of the suggested complexes in a series of concrete instances, and was thus enabled to impart to the Duclaux hypothesis a more complete and consistent form.

The most direct method of revealing the compensating ions is found to be the

potentiometric method of the ion determination, first introduced in application to the colloidal systems by Pauli and his school.

As stated earlier, the fundamental condition of the potentiometric measurements in the colloidal systems is the concept, which is particularly clearly expressed in Pauli's researches, that the measured difference of potentials determines the ion concentration in the double electrical layer enveloping the colloidal particles. In other words, it is considered that potentiometrically measured concentration of the compensating ions represents its total content in the colloidal system, and that this quantity is equivalent to the entire number of charges (of opposite sign) carried by the colloidal particles.

Variations of Colloidal Systems in Their Interaction with Electrolytes

From the analysis as outlined above it follows that the particles of lyophobe colloidal systems are regarded as large polyvalent ions surrounded by the ordinary, simple ions of the opposite sign (i.e., the compensating ions), while the concentration of the latter is high in the proximity of the particles and sharply falls off with the distance from the particles into the enclosing liquid medium. It was thought that for the colloids, well purified by the dialysis, the entire content of the electrolyte in the system is, practically, exhausted by the above colloidal electrolyte, and that for the stable colloidal system the presence of other ions and the electrolytes in the intermicellar liquid is not necessary.

Such a conception of the nature of the lyophobe colloidal systems, in the explicit and implicit form, was also regarded as the basis of all principal theories of the coagulation of lyophobe colloids. This notion includes, first of all, the assumption of the constancy of the number of charges on the colloidal particle, non-varying under the physical actions upon the colloids and by the change of the concentration of electrolytes in the intermicellar liquid. Referring to the constancy of the number of charges which enter into the interior boundary of the electrical double layer, i.e., enter into the phase of the colloidal particle itself, determining thereby the total potential difference between the particle and the intermicellar liquid.

The constancy of the number of charges entering into the physical surface of the colloidal particle, accepted by all existing theories of coagulation, testifies to the constancy of the number of the ionogene groups on this surface and, consequently, the invariability of the surface during the coagulation process. In this connection, the theories which have devoted much attention to the mechanism of this process, notably those of Haber[299] and Zsigmondy,[300] have laid as their basis the presence of the constant forces of attraction between the surfaces of particles; whilst the variation of stability, characteristic to the coagulation, has been interpreted exclusively by the resulting change of the electrostatic forces of repulsion between the charged particles, which thus prevent them in a stable colloidal solution approaching near enough so as to allow the forces of attraction to come into play.

As a quantitative measure of the electrostatic forces of repulsion, acting between the particles, is accepted the value of the electrokinetic ζ potential, equal to the difference of the potentials between the interior parts of the intermicellar liquid, remotely situated from the particle surface, and the " boundary surface," i.e., that surface which separates the liquid skin attached to and carried by the particle from the remainder of the liquid mass. The selection of ζ potential as a measure of the repulsion forces is explained by the fact that this is the only value which is capable of the quantitative assessment, and, doubtless, is intimately bound up with the magnitude of the forces of repulsion. It is worth noting that the best developed method of the potentiometric measurement of the colloidal particles is the cataphoretic method.

In accordance with the above concep-

tions, all the modern coagulation theories consider the decrease of the stability of the system resulting through the addition of the electrolytes to the colloidal solution, as a consequence of the redistribution or the replacement of the compensating ions, which form the outer boundary of the electrical double layer, leading to the fall of ζ-potential to a certain critical value.

These views have been expressed with particular clarity in the works of Müller[301] and Rabinovitch.[302] As a cause of the coagulation, Müller regards solely the redistribution of the ions at the outer boundary of the double layer, which is being compressed on the addition of electrolytes, and thus must necessarily reduce ζ-potential, if the constancy of the number of charges on the surface of the separation is maintained. Rabinovitch, side by side with the electrostatic compression of the diffusion part of the outer boundary of the double layer, interprets the decrease of ζ-potential as a result of the alteration of the number of charges, evoked by the adsorption interchange of the ions in the " Helmholtz " portion of the double layer.

Hence the chief role in the reduction of ζ-potential and the general stability of the colloidal system is attributed to the predominant accumulation in this region of the electrical double layer of the polyvalent and strongly adsorbing ions with the simultaneous removal from it of a smaller amount of the compensating ions of inferior valency.

Thus the modern theories of coagulation associate the stability of the colloidal systems exclusively with the state of the outer boundary of the double layer.

From the foregoing discussion it is readily seen that in the prevalent notions on the stability of the lyophobe colloids the ζ-potential was adopted as a measure of the stability of the colloidal system, determining the electrostatic forces of repulsion that prevent the cohesion of the charged particles; whereas the attractive forces, promoting this cohesion between totally or partly charged particles, have been regarded as perfectly constant, characterizing the particle surface proper, which did not alter in the coagulation process.

The ideas, introduced of late by Karguin and Rabinovitch,[303] of the variability of the surface of the colloidal particles during the coagulation process, necessitates one to consider the variations not only of the repulsion forces, but also the forces of attraction, which are connected with the change of the number and the nature of the ions adsorbed on the surface of the particles, due to addition of a new electrolyte.

Parallel with these two factors, changing both the attractive and repulsion forces between the particles, there certainly may also be present the factors, which reduce only the forces of repulsion; the adsorption of compensating ions (their diffusion into the inner part of the outer boundary of the double layer), decreasing the number of charges on the surface of the phase separation and, consequently, ζ-potential, as has been pointed out by Rabinovitch,[302] associated with the variation of the qualitative and quantitative constitution of the double layer.

Which of these forces play the predominant role—those which augment the forces of attraction or those which reduce the forces of repulsion—is determined in each case by the specific peculiarities of a given sol and the added electrolyte. As yet there is no method available for their quantitative estimation.

(To be continued)

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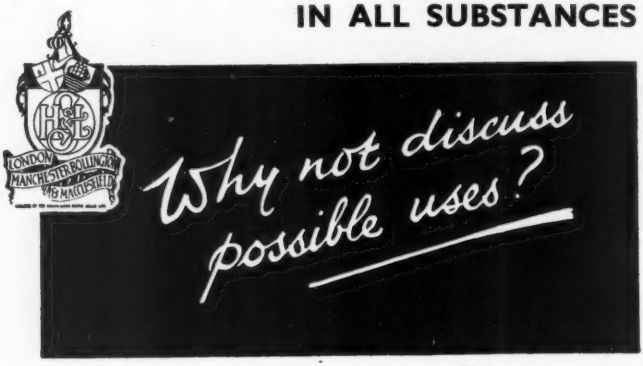

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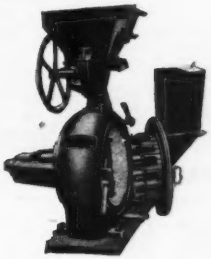

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